A DESCRIPTION OF THE

WATER SUPPLY SYSTEM OF THE CITY OF NEW YORK

1952

DEPARTMENT OF WATER SUPPLY
GAS AND ELECTRICITY

HON. VINCENT R. IMPELLITTERI
MAYOR

DOMINICK F. PADUANO
COMMISSIONER

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JUNE, 1952

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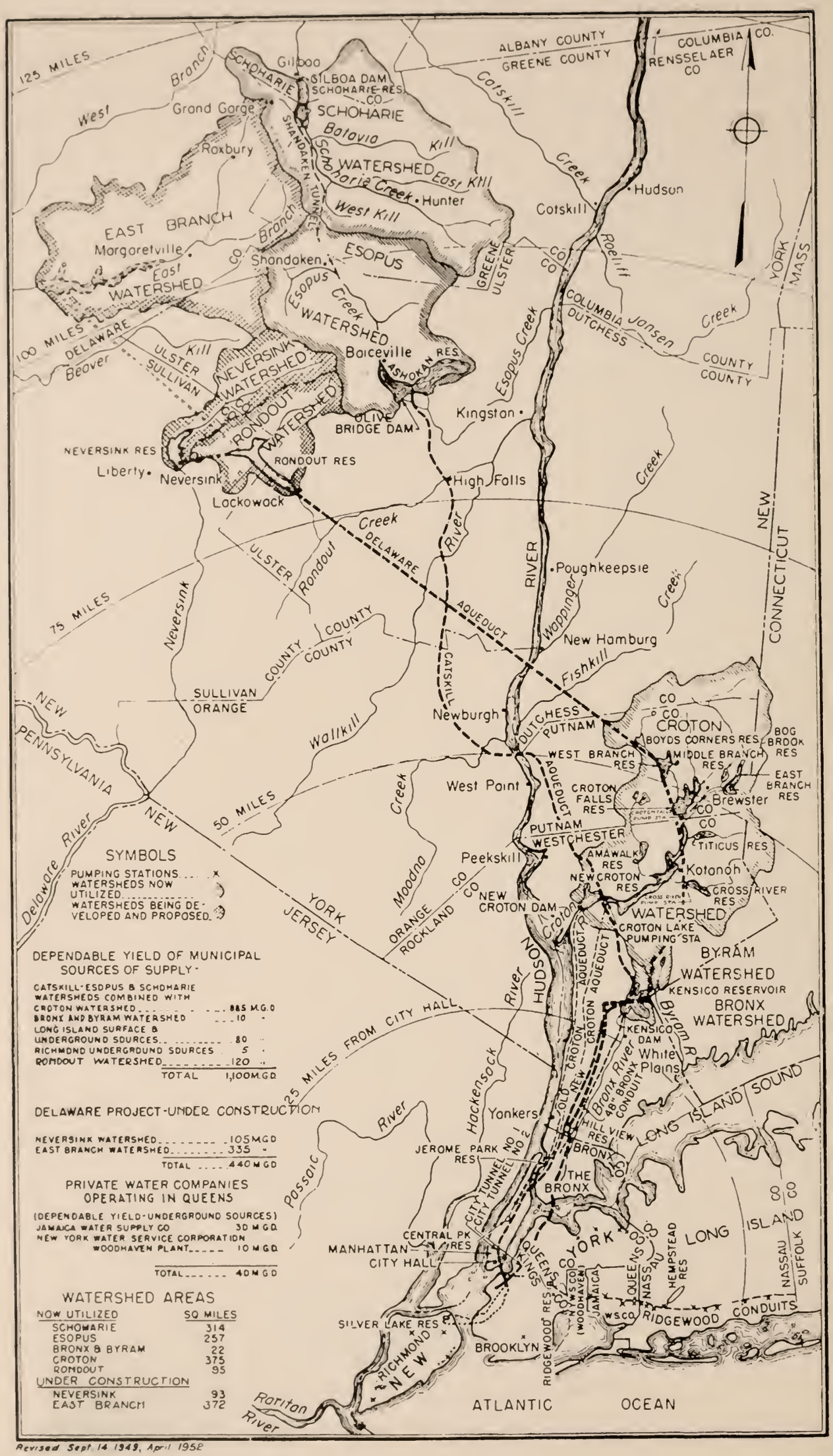
CONTENTS

	Page
Historical	5
Watersheds, Reservoirs and Aqueducts	12
Croton System	12
Old Croton Aqueduct	14
New Croton Aqueduct	16
Croton Lake Pumping Plant	20
Croton Falls and Cross River Pumping Plants	20
Bronx and Byram Systems	20
Catskill System	22
Shandaken Tunnel	24
Gilboa Dam	24
Schoharie Reservoir	24
Ashokan Reservoir	26
Kensico Reservoir	29
Hillview Reservoir	30
Silver Lake Reservoir	30
Catskill Aqueduct	34
City Tunnel No. 1	35
City Tunnel No. 2	37
Rondout Creek Supply	37
Ridgewood System	39
Queens System	41
Richmond System	43
Hudson River Pumping Plant	43
Utilization of Present Sources of Water Supply	43
Quality of Water	44
Distribution Systems	47
High Pressure Fire Service	51
Consumption and Waste of Water	52
Private Water Companies	54
Supply to Communities Outside of New York City	54
Water Revenue	55
Financial	57
Administrative Officers	57
Table of Distributing Mains in Use at End of 1951	59
Table of Storage Reservoirs in Watersheds	60
Table of Main Aqueducts and Pipe Lines	61
Table of Distribution Reservoirs and Standpipes	62
Table of Population and Consumption of Water	63
Profile of Catskill and Delaware Aqueducts	64



Revised Sept 14 1949, April 1952

THE WATER SUPPLY
OF THE CITY OF NEW YORK

HISTORICAL

The present City of New York is the result of the consolidation in 1898 of various communities located in the vicinity of New York Harbor, which are now included in the boroughs of Manhattan, the Bronx, Brooklyn, Queens and Richmond. Their water supplies were developed without regard to the present city limits and it was not until 1917 that New York was served by a system planned for the city as a whole.

The borough of Manhattan, constituting the old City of New York, had, until 1842, no general water supply system, although its population at that time amounted to over 300,000. The early settlers of Manhattan Island obtained water for domestic purposes from shallow wells which were at first constructed by individual enterprise. The first public well was dug in front of the old fort at Bowling Green on or about the year 1677. Additional public wells were sunk in the streets from time to time, as required, the city bearing part of the expense and part having been assessed on the property benefited. In 1776, when the population reached 22,000, a reservoir was constructed on the east side of Broadway between Pearl and White Streets. Water was pumped from wells sunk near the famous "Collect" Pond east of the reservoir, and from the pond itself, and was distributed through hollow logs laid in the principal streets. In 1800 the Manhattan Company (now the Manhattan Bank) sunk a well at Reade and Centre Streets, pumped water therefrom into a reservoir on Chambers Street and distributed it thence through wooden mains to a portion of the community which, at that time, consisted of about 60,000 inhabitants. The maximum amount supplied by this company was 700,000 gallons a day. In 1830 a tank for fire protection was constructed by the City at 13th Street and Broadway. This tank was filled by pumping from a well sunk for the purpose, and the contents distributed through two lines of 12-inch cast iron pipe, one extending down The Bowery to Chatham Square and the other through Broadway and Canal Street. This was the beginning of the public water works of New York City. The well was 16 feet in diameter and 112 feet in depth, 98 feet of which was excavated through solid rock. At the bottom of the well two galleries extended, 6 feet by 4 feet, one 25 feet, and the other 75 feet in length. The daily yield of the well amounted to 21,000 gallons and was pumped by a 12 H.P. steam engine into a cast iron tank of 43 feet diameter and 20½ feet height, enclosed in an octagonal stone building.

As the population of the City increased, the well waters became brackish or polluted with organic matter and insufficient in quantity. To meet ordinary domestic needs, main dependence was upon cisterns supplied from rain caught upon the roofs; water secured from a few springs in the upper part of the City was sold from large casks at two cents a pail.

After entertaining numerous schemes for a suitable source of supply, among which were Rye Pond, Bronx and Byram Rivers in Westchester County, Passaic River in New Jersey and artesian wells in Manhattan Island, it was decided to built an aqueduct from the Croton River to the City, to be supplied by one storage reservoir; this aqueduct (known today as the Old Croton Aqueduct), with a capacity of 90 m.g.d. (million gallons daily), was placed in service in 1842, its completion having been expedited by the great conflagration of 1835. This was an event of great importance in the history of older New York. The distribution reservoirs were at Forty-second Street (abandoned in 1890), and in Central Park, south of Eighty-sixth Street (abandoned in 1925). In the drought of 1869-70 the right was secured to draw down six of the lakes and ponds in the Croton watershed. Boyd's Corners Reservoir was then constructed in 1873 and Middle Branch in 1878. In due course the old Croton aqueduct became inadequate, and in 1883 a commission was formed to build a second one from the Croton watershed, as well as additional storage reservoirs in that watershed. The second aqueduct, known as the New Croton Aqueduct, was under construction from 1885 to 1893 (though it was used as early as 1890), and has a capacity of 300 m.g.d.

West Bronx was annexed to the old City of New York in 1874 and East Bronx in 1895. The system of the New York and Westchester Water Company which supplied the villages of Williamsbridge and Wakefield and the towns of Westchester and Pelham from Hutchinson River was acquired by the City in 1903; the Upper New York City Water Company which supplied the village of Eastchester was acquired by the city in 1905. A municipal supply from the Bronx and Byram Rivers was made available in 1895. The waters from these watersheds, yielding about 20 m.g.d., were originally delivered into a 48-inch cast iron pipe line over fifteen miles long, leading from the former Kensico Lake to the Williamsbridge reservoir, in the Bronx. In 1916 this lake was merged in the new Kenisco reservoir, and at that point the waters from the Bronx and Bryam watersheds became merged with the new Catskill supply.

The Williamsbridge Reservoir was abandoned in 1934 and the pipe line, thereafter, was directly connected to this distribution system.

The former City of Brooklyn, like the former City of New York, did not develop a public water supply system until its population had reached nearly 300,000, the use of local wells and cisterns being the only sources of supply prior to 1859. In that year the city began delivering water collected on the south side of Long Island into its distribution system, pumping this water at the Ridgewood north side pumping station. The original works

Croton Dam and Spillway, with flood waters discharging over the waste weir.

ran easterly to the Hempstead Valley. Later they were extended to Massapequa, Long Island, and the large Milburn and the Ridgewood South Side pumping stations constructed.

For the Borough of Queens no municipal waterworks of magnitude had been constructed. Prior to 1913 the First Ward was served by three local municipal pumping stations and by private water companies. Between 1913 and 1917 it was served largely from the Brooklyn watershed. The Third Ward, prior to 1917, was served by two municipal pumping stations, while the Second, Fourth and Fifth Wards were supplied by private water companies, their source of supply being ground water collected by means of driven wells.

On April 20, 1922, that part of the plant of the Citizens Water Supply Company supplying the Second Ward was acquired through condemnation by the City, and at present is municipally operated, and on April 15, 1931, the Fifth Ward plant of the Long Island Water Company was acquired by purchase. The Citizens Water Supply Company was incorporated June 1, 1893, and began to supply water the following year; the Long Island Water Corporation was incorporated March 27, 1884, and its first water works system at Far Rockaway was constructed in 1885.

Prior to 1917 the Borough of Richmond was dependent for its supply on ground water from wells. Until 1909, except as to Tottenville, it was served by private water companies. The principal of these companies, the Staten Island Water Supply Company, incorporated September 19, 1878, and the Crystal Water Supply Company, incorporated March 16, 1883, were in 1909 acquired by the City. The last of the private companies in this borough (the South Shore Water Works Company, which was originally incorporated on July 10, 1889), was acquired by the City in 1917.

As early as 1900, the necessity was foreseen for providing a large additional water supply for the use of Greater New York and in 1902 definite steps were taken to formulate and execute such a plan. In that year a commission of engineers was appointed which, after careful study, recommended that the city go to the Catskills for additional water. In 1905 the Board of Water Supply—not to be confused with the Department of Water Supply, Gas and Electricity—was created by act of the Legislature, and proceeded forthwith to plan and construct the works for impounding the waters of the Esopus, one of the four watersheds in the Catskills, upon which the city had planned to draw, and for delivering such waters throughout New York City. This monumental work, commonly known as the Catskill system, was successfully completed and turned over to the Department of Water Supply, Gas and Electricity for maintenance and operation in 1917. The second stage of the Catskill development, which involved the construction of the Schoharie reservoir and Shandaken tunnel, was finished and turned over to the Department on June 1, 1928. The Schoharie supply was used on and after February 3, 1924, when the tunnel was opened. Under

The Kenisco Dam and portion of the reservoir, with the Kensico lower effluent chamber in right background.

a resolution of the Board of Estimate and Apportionment, adopted June 17, 1921, the Board of Water Supply was empowered to investigate sources of additional supply for the City and the more adequate extension of existing and future water supplies.

In 1927 the Board of Water Supply submitted to the Board of Estimate and Apportionment a plan recommending the upper portion of the Rondout watershed and the tributaries of the Delaware River lying wholly in the State of New York as the most available and economical sources of new water supply for New York City. The project was approved by the Board of Estimate and Apportionment in 1928, and by the Water Power and Control Commission in 1929, but was held back because of action brought by the State of New Jersey in the U. S. Supreme Court, to enjoin the City and State of New York from using the waters of any of the tributaries of the Delaware River. In May, 1931, the U. S. Supreme Court upheld the right of New York City to augment its water supply from the headwaters of the Delaware River. The city was permitted to divert only 440 m.g.d. from the tributaries of the Delaware River instead of the 600 m.g.d. planned; but the Court left the way open for direct application for new allocations as the needs of the future might require. It is estimated that the upper portion of the Rondout watershed will yield 120 m.g.d. The combined watersheds will therefore yield 560 m.g.d. The Upper Rondout and Delaware watershed development, including the proposed aqueduct to the city, is generally referred to as the Delaware system.

Construction of the Delaware Project was begun in March, 1937, with the expectation that it would require about eight years to develop the first stage and deliver an additional supply of water to the City. The Second World War intervened, however, to prevent the completion of this work on time as difficulties in procuring materials and equipment began to be experienced in the middle of 1941. Beginning in 1942 contractors were released from their obligations to install materials then unobtainable and in the summer of 1943 operations were entirely suspended due to the inability on the part of the contractors and of the City to obtain necesary materials and equipment owing to restrictions imposed by the Federal Government in connection with the prosecution of the war. At this time the tunnels from Rondout Creek to Hillview Reservoir and the gate chambers at Hillview, Kensico and West Branch Reservoirs were completed; but valves, sluice gates and other operating equipment for the tunnels and chambers were lacking and Merriman Dam, which was to impound the waters of Rondout Creek to form Rondout Reservoir, was barely begun.

When it became evident that construction on the Delaware system would have to be suspended it was believed feasible to attempt emergency operation with that portion of the work that had been completed. With the aid of improvised temporary operating equipment the tunnel from Kensico Reservoir to Hillview Reservoir was placed in emergency operation in April, 1942,

The Ashokon Reservoir showing the dividing weir dike, the Ashokan bridge and portions of the east and west basins of the reservoir.

and the tunnel from West Branch Reservoir to Kensico Reservoir in March, 1943. At the site of the uncompleted Merriman Dam the construction of a small inlet chamber and tunnel connecting to the Delaware tunnel permitted the diversion of the stream flow of Rondout Creek, without benefit of storage, to be begun in April, 1944, which provided an additional supply to the City.

In December, 1946, new contracts were awarded for the completion by 1951, of those items that had been deferred because of the war. Neversink Reservoir and appurtenant works is expected to be finished by 1953; Pepacton Reservoir, etc., on the east branch of the Delaware River in 1955.

In May, 1951, the temporary connection diverting the stream flow of Rondout Creek into the Delaware Aqueduct was sealed and the impounding of the Creek's waters in the Rondout Reservoir began. Water was first delivered through the permanent effluent works on June 18, 1951.

WATERSHEDS, RESERVOIRS AND AQUEDUCTS

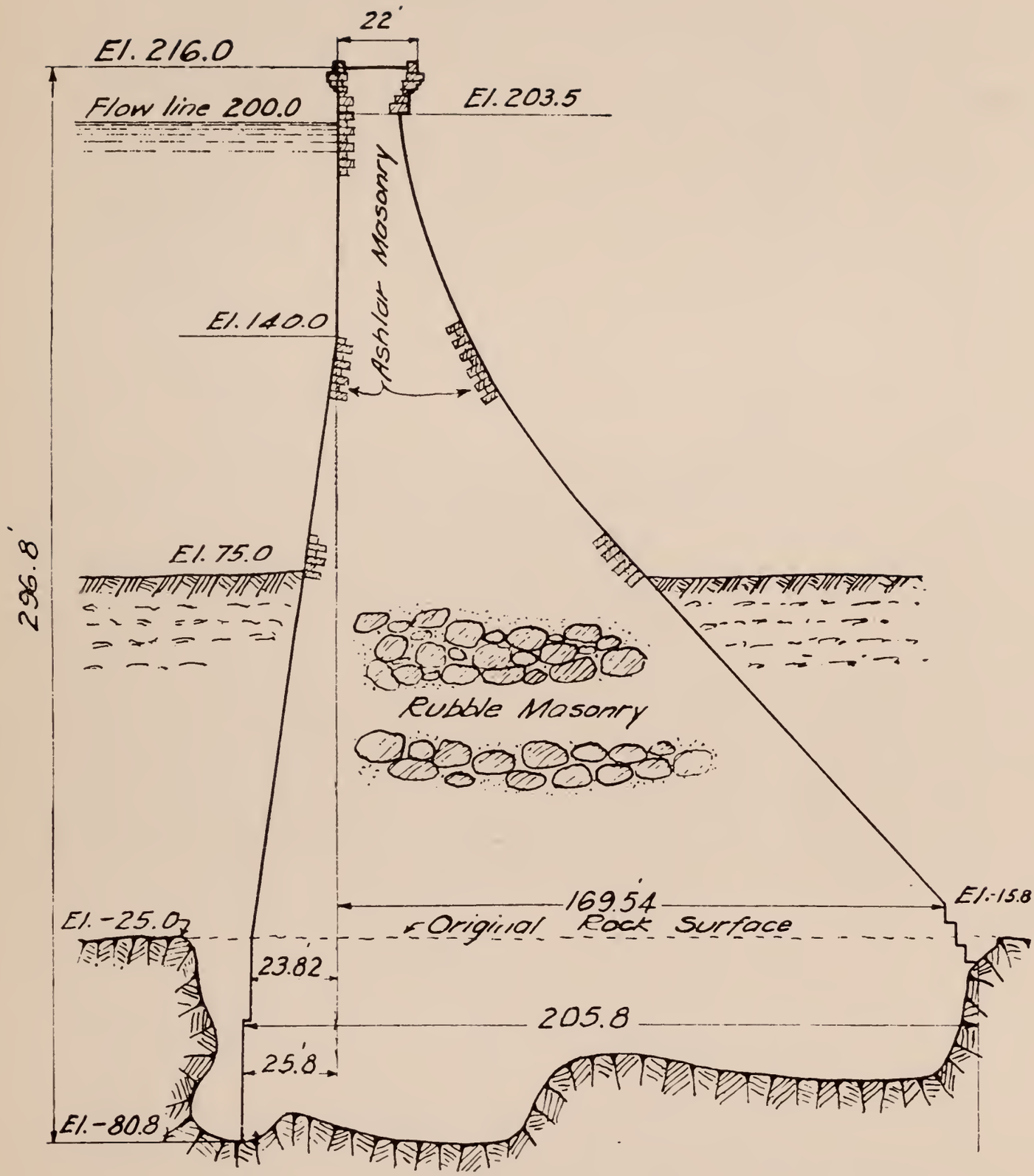
The municipality now has available as sources of supply, (1) Croton River in Putnam and Westchester Counties, where the water is collected in 12 reservoirs and six controlled lakes, (2) Bronx and Byram Rivers in Westchester County, where the water is stored in Byram and Wampus ponds and in the enlarged Kensico reservoir, now part of the Catskill system, (3) Schoharie and Esopus Creeks in the Catskills, where water is collected in the Schoharie and Ashokan Reservoirs, (4) Rondout Creek in the Catskills, where water is collected in the Rondout Reservoir, (5) Brooklyn and Ridgewood watersheds and on the south side of Long Island, where water is obtained from small streams, infiltration galleries and driven wells, (6) Borough of Queens, where water is obtained from driven wells, (7) Borough of Richmond, where water is obtained from driven wells.

Brief Descriptions of the various systems follow:

CROTON SYSTEM

The Croton River is formed by three branches, known respectively as the East, Middle and West Branches, which rise in the southern part of Dutchess County, flow in a southerly direction through Putnam County and unite near its southerly boundary. The river continues in a southwesterly direction across Westchester County to the Hudson River, into which it empties at Croton Point, 22 miles from the northerly limits of New York City. The principal tributaries of the Croton are the Titicus, Cross, Kisco and Muscoot Rivers.

The watershed extends about 33 miles north and south and eleven miles east and west; it lies almost entirely within the State of New York, only a



NEW CROTON DAM

Maximum Section

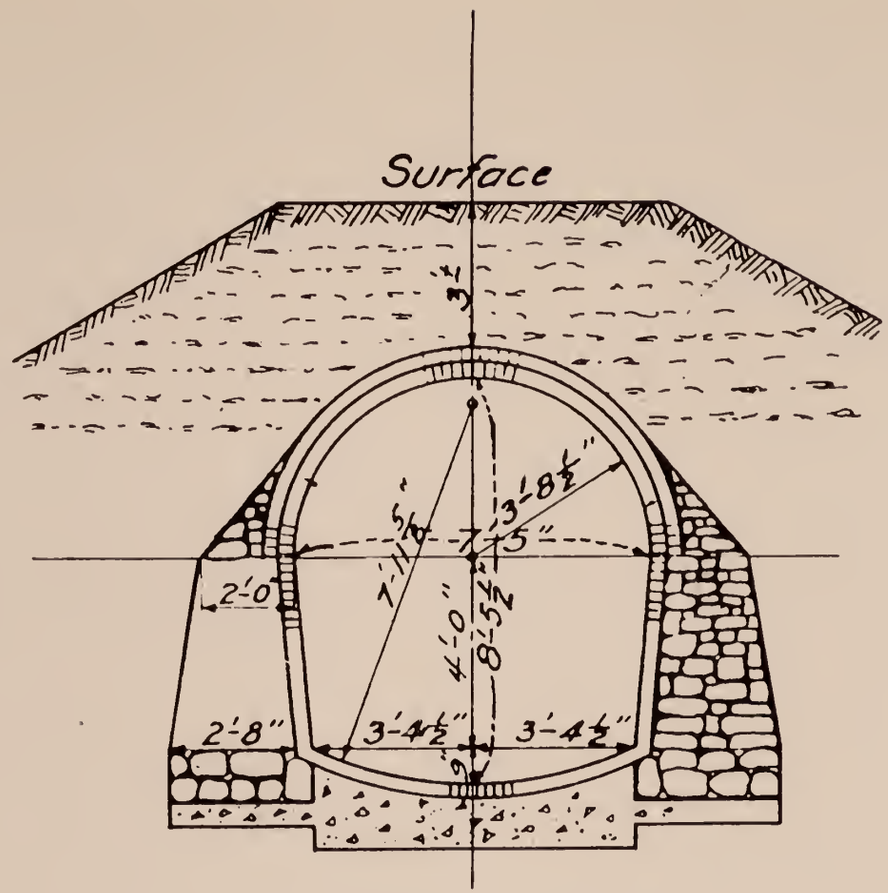
Note:—Elevations refer to Croton datum, which is 0.45 ft. below mean sea level at Sandy Hook.

small portion being in Connecticut. Its area is 375 square miles above the new Croton dam, and it may be relied upon to yield at least 315 m.g.d., when considered by itself and 330 m.g.d. when analyzed in combination with the Schoharie and Esopus Watersheds. The yield in the past 83 years averaged 400 m.g.d. Its waters are collected through twelve storage reservoirs and six controlled lakes having an aggregate storage capacity of 103,075 m.g. The lowest and largest of the reservoirs is Croton Lake, which is formed by the new Croton dam; it is about 20 miles in length and has an available storage capacity of 33,815 m.g. The population on the watershed is about 50,000, mainly concentrated in several small towns and villages. The watershed is very hilly. The surface soil is composed principally of sand and gravel; clay, hardpan and peat are found in a few localities, but only to a very limited extent. The rock formation consists generally of gneiss. Strata of limestone, some micaceous and talcose slates, veins of granite serpentine and iron ore occur in a few places. The Croton water is a soft water, although not as soft as the Catskill water. To protect the supply a margin about 300 feet has been acquired by the city around all reservoirs and along some of the tributary streams.

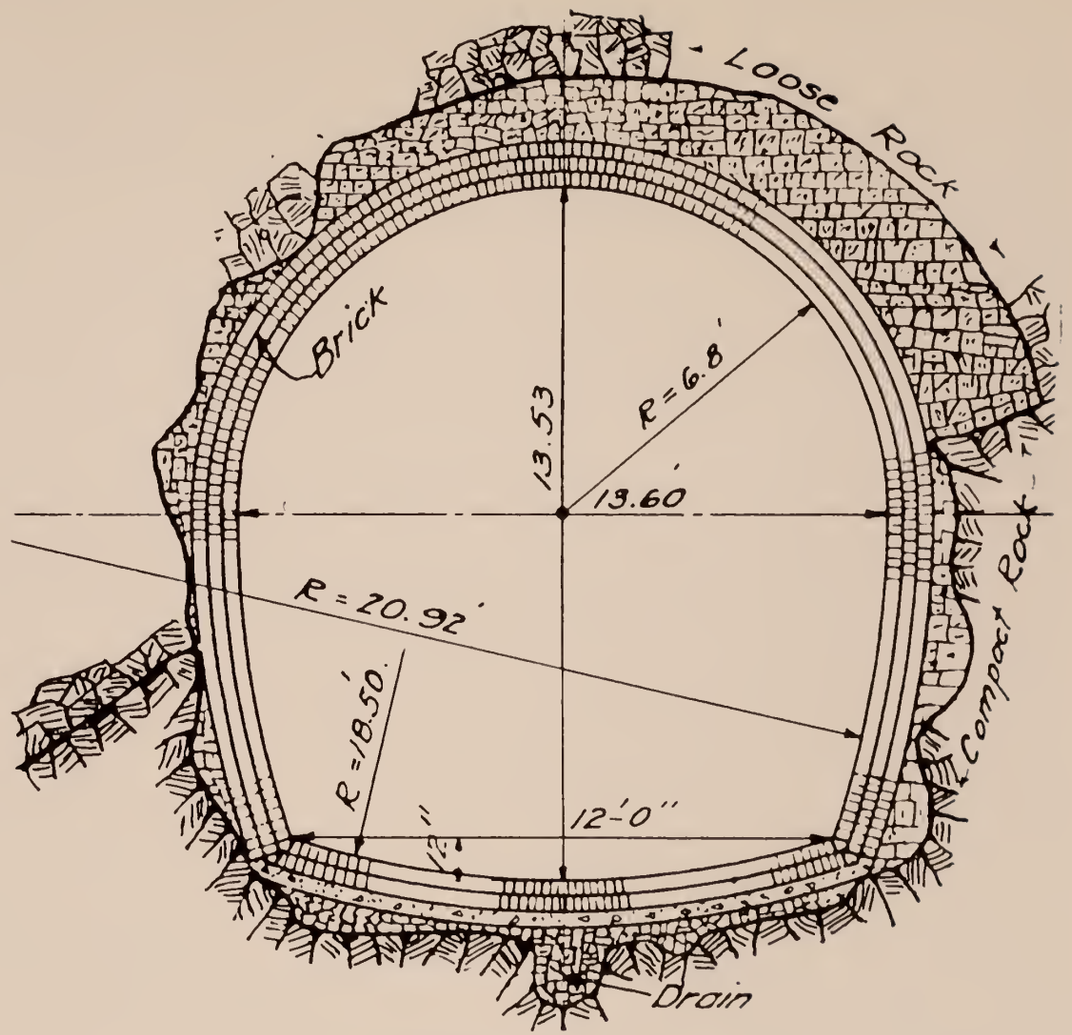
The new Croton reservoir was constructed between 1892 and 1905 at a cost of approximately $17,000,000, including land, the cost of the dam itself having been close to $7,000,000. The dam is built across the valley of the Croton River, three miles above the point where it empties into the Hudson River. Including a curved spillway 1,000 feet long, it has a total length of 2,168 feet. It is founded upon bed rocks of gneiss and limestone. The maximum width at the base is 206 feet, the maximum height 296.8 feet, and minimum thickness at top 18 feet. With the exception of 128 feet of earth section with masonry core, the entire dam is partly of "cyclopean," but mainly of rubble masonry, faced above the backfilling with ashlar masonry. The spillway of the dam is at elevation 199.55 feet; two feet permanent flashboards are set on top of the spillway, making the elevation of the flow line 201.55 feet.

Old Croton Aqueduct

The Old Croton aqueduct was constructed in 1837-1842. It begins at Croton Lake, follows the Croton River to a point near its mouth, and then the Hudson River to Yonkers. Here it crosses the Sawmill river and Tibbets Brook, and continues to the Harlem river, which it crosses on Highbridge, thence to the receiving reservoir in Central Park. The standard section is of horse-shoe shape containing 53.34 square feet. It is founded on concrete 3 to 12 inches thick; the side walls are of rubble masonry. Sides and bottom are lined with 4 inches of brick, and the top arches of 8 inches of brickwork. Valleys, as a rule, are crossed on earth embankments with dry rubble walls. The grade in general is 0.021 foot per 100. Harlem River is crossed by means of a 90-inch steel pipe, which is carried by a masonry



OLD CROTON AQUEDUCT



NEW CROTON AQUEDUCT

Grade Tunnel
In Compact and Loose Rock

structure with central steel-arch span, known as Highbridge. Manhattan Valley is crossed by means of two lines of 36-inch, one 48-inch, and one 60-inch cast iron pipe.

While repairs to this aqueduct have been made from time to time, and some short sections built on embankments have been reconstructed, it is still in generally good condition, but is capable of deliverying without excessive leakage only about 35 m.g.d., or less than one-half of the full capacity for which it was originally designed.

Practically all the Croton water reaching Manhattan is carried to the gatehouse at 135th Street and Convent Avenue, except that taken from the New Croton Aqueduct at the 179th Street pumping station. From the 135th Street gatehouse all Croton water goes by gravity into the mains either directly or through the distributing reservoir in Central Park, except that which is sent to the 98th Street pumping station, the Central Park pumping station and the 40th Street hydraulic pumping station.

New Croton Aqueduct

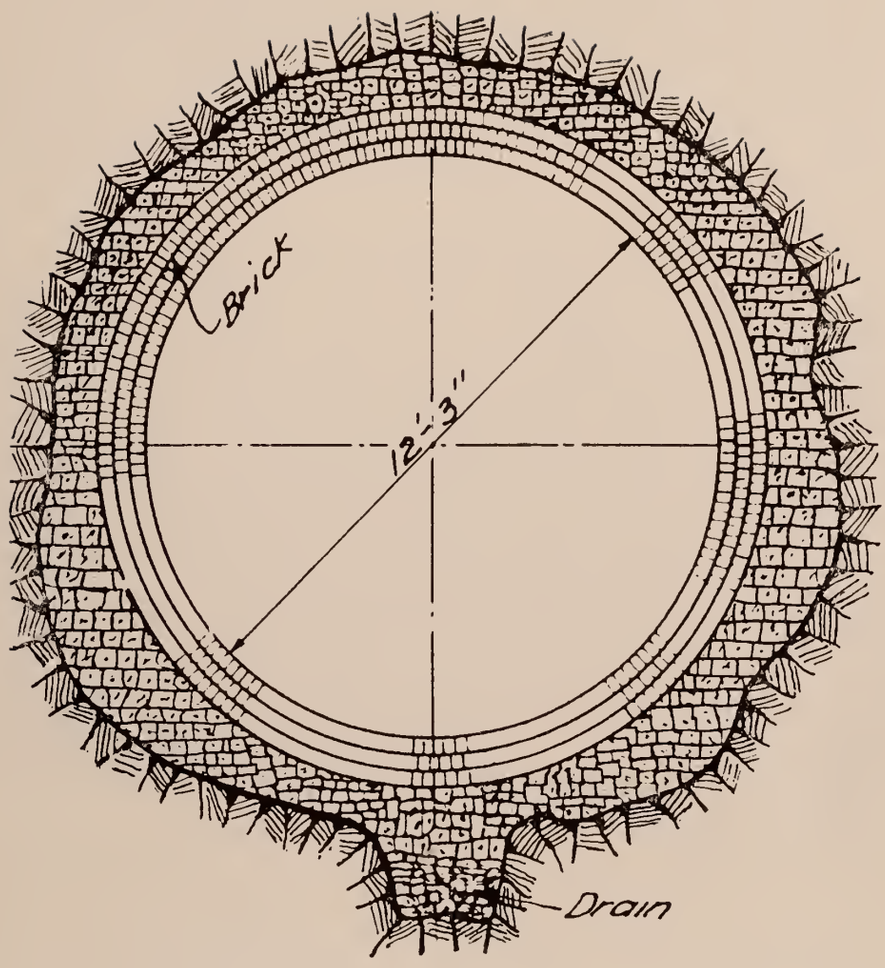
The New Croton Aqueduct was constructed in 1885-1891. It consists essentially of three parts:

1st—A masonry conduit from the inlet gatehouse which is located near the Old Croton Dam, and three miles north of the new Croton Dam, to Mosholu Avenue near the Jerome Park distributing reservoir, a distance of 23.92 miles. The invert at the gatehouse is 60 feet below the elevation of the spillway at the New Croton Dam, the grade thence being uniformly 0.7 foot per mile, except for the inverted siphon under Gould's Swamp near Tarrytown. The nominal capacity of this stretch is 300 m.g.d. This portion of the aqueduct is of horse-shoe section, except the Gould's Swamp siphon, which is circular, 14 feet 3 inches internal diameter and 1,135 feet long. It was constructed mainly in tunnel and follows a southerly direction along Pocantico River, Sawmill River and Tibbets Brook. The aqueduct is lined with brickwork, varying from 12 to 24 inches for the sides and arch, and from 8 to 24 inches for the invert, according to external pressure; the invert was laid on a foundation of concrete and rubble. The space between the sides and roof of the tunnel excavacation and the brick lining was filled with rubble masonry to a level of four feet over the crown of the intrados of the arch.

2nd—A masonry conduit under pressure from Mosholu Avenue to gatehouse on Manhattan Island at 135th Street and Convent Avenue. This portion forms a long inverted siphon; its cross-section is circular, the inner diameter being 12 feet 3 inches, except in the tunnel under the Harlem River, where it was reduced to 10½ feet to increase the velocity of current in order to prevent deposit of silt. To avoid heavy land damages the aqueduct at Mosholu Avenue was depressed 115.64 feet by an incline having a 10 per cent grade,

Jerome Reservoir

Hillview Reservoir



NEW CROTON AQUEDUCT

Pressure Tunnel

and continued on a grade of 0.7 foot per mile, to a point within 1,100 feet of the Harlem River. Here the aqueduct was lowered 127.5 feet on a 15 per cent grade, then 172 feet, passing under the Harlem River 300 feet below high water, descending on a 1 per cent grade. On the Manhattan side the conduit ascends from the shaft to the gatehouse at a grade of 0.65 foot per 1,000 feet. The nominal carrying capacity of this stretch of the aqueduct is 250 m.g.d., the difference being allowed for the water taken out of Jerome Park Reservoir for the Bronx supply; this capacity is further reduced by the additional head maintained at the 135th Street gatehouse.

3rd—Pipe lines from 135th Street Gatehouse. From this point, five lines of steel mains, two 60 inches, and three 48 inches in diameter, are laid to 133rd Street and Convent Avenue, where they connect with seven lines of 48-inch cast iron pipe. Three of these mains are used for conveying water to Central Park Reservoir; the other four mains connect with the distribution system at various points.

Croton Lake Pumping Plant

The pumping plant installed at the Croton Lake gatehouse is comprised of three motor-driven centrifugal units each of 60 m.g.d. capacity.

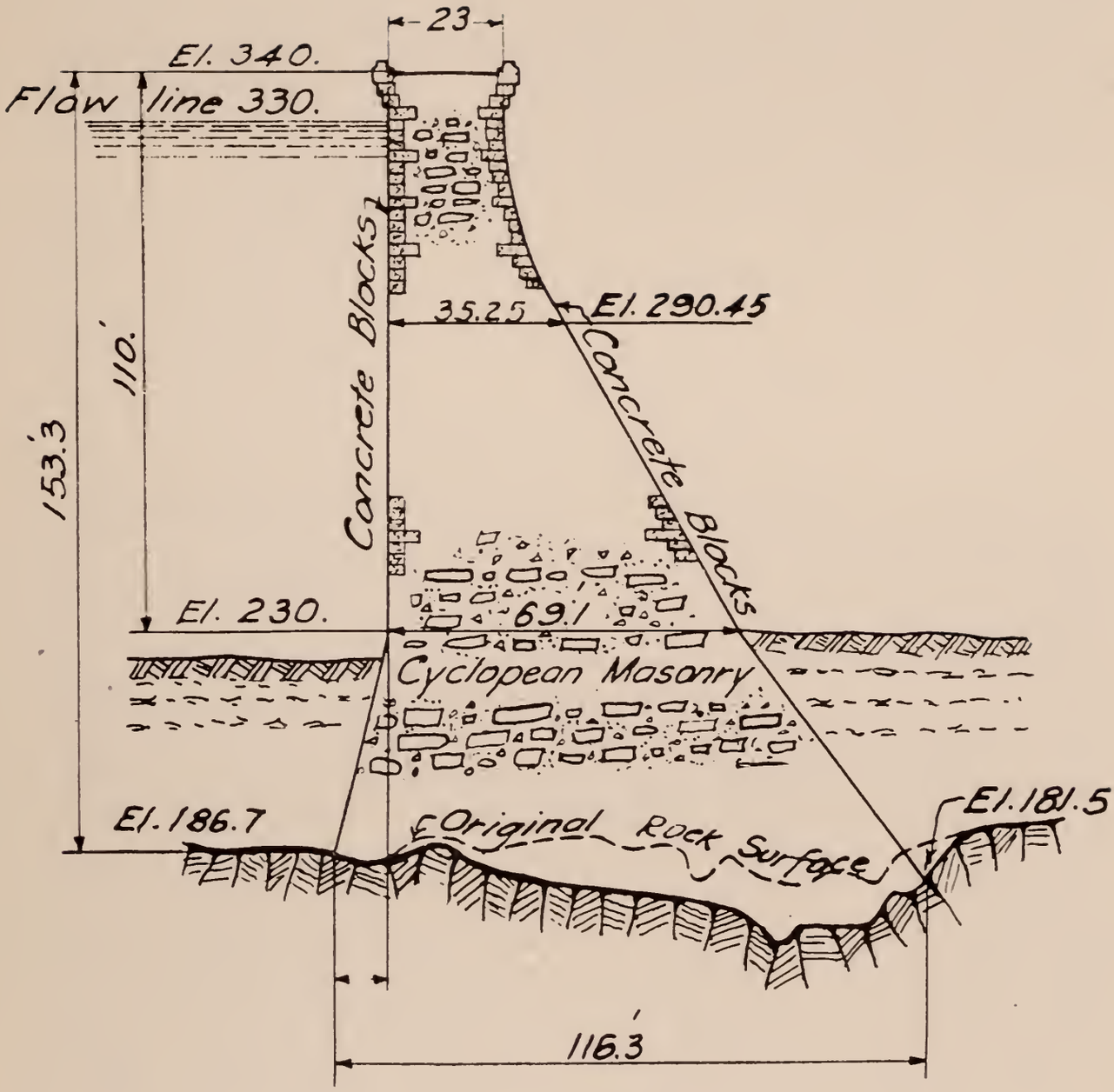
The plant, which has been in operation at various times since March 15, 1932, is designed to lift water from the Croton Lake gatehouse, discharging it through a 72-inch steel line approximately 1,600 feet long, into the Catskill Aqueduct, at a level of about 170 feet above that of the surface of Croton Lake. This station is not operated continuously, but only over such periods as may be necessary to equalize the difference in the quantity of stored water in the Catskill and Croton watersheds, thus providing greater flexibility in the operation of the City's water supply, or to permit an increased delivery of water through the Catskill aqueduct to Kensico reservoir.

Croton Falls and Cross River Hydraulic Pumping Plants

At these stations, water is pumped by hydraulic turbines from Croton Falls and Cross River Reservoirs into the Delaware Aqueduct at Shafts 11 and 13, respectively. This makes it possible to deliver more water from the Croton Watershed to the City at high level, thereby reducing the pumping costs incurred in utilizing Croton water in the high level areas of the City. These stations also provide for greater flexibility in the operation of the City's water supply.

BRONX AND BYRAM SYSTEMS

Work on the development of the Bronx River and Byram River watersheds, covering 13.33 and 8.66 square miles, respectively, was commenced in 1880, but owing to long negotiations with riparian owners on the Byram River in Connecticut, the entire construction was not completed until 1897, although part of the supply was made available in 1884.



CROSS RIVER DAM

MAXIMUM SECTION

Note:—Elevations refer to Croton datum, which is 0.45 ft. below mean sea level at Sandy Hook.

A small diverting dam, about 1100 feet north of the Connecticut State line, was constructed on the Byram River (the outlet of Byram Lake), just below the point where the Wampus River (the outlet of Wampus Pond), unites with it. From this dam the waters of the Byram and Wampus rivers are led into the Bronx watershed through a tunnel and open channel a distance of 3,800 feet.

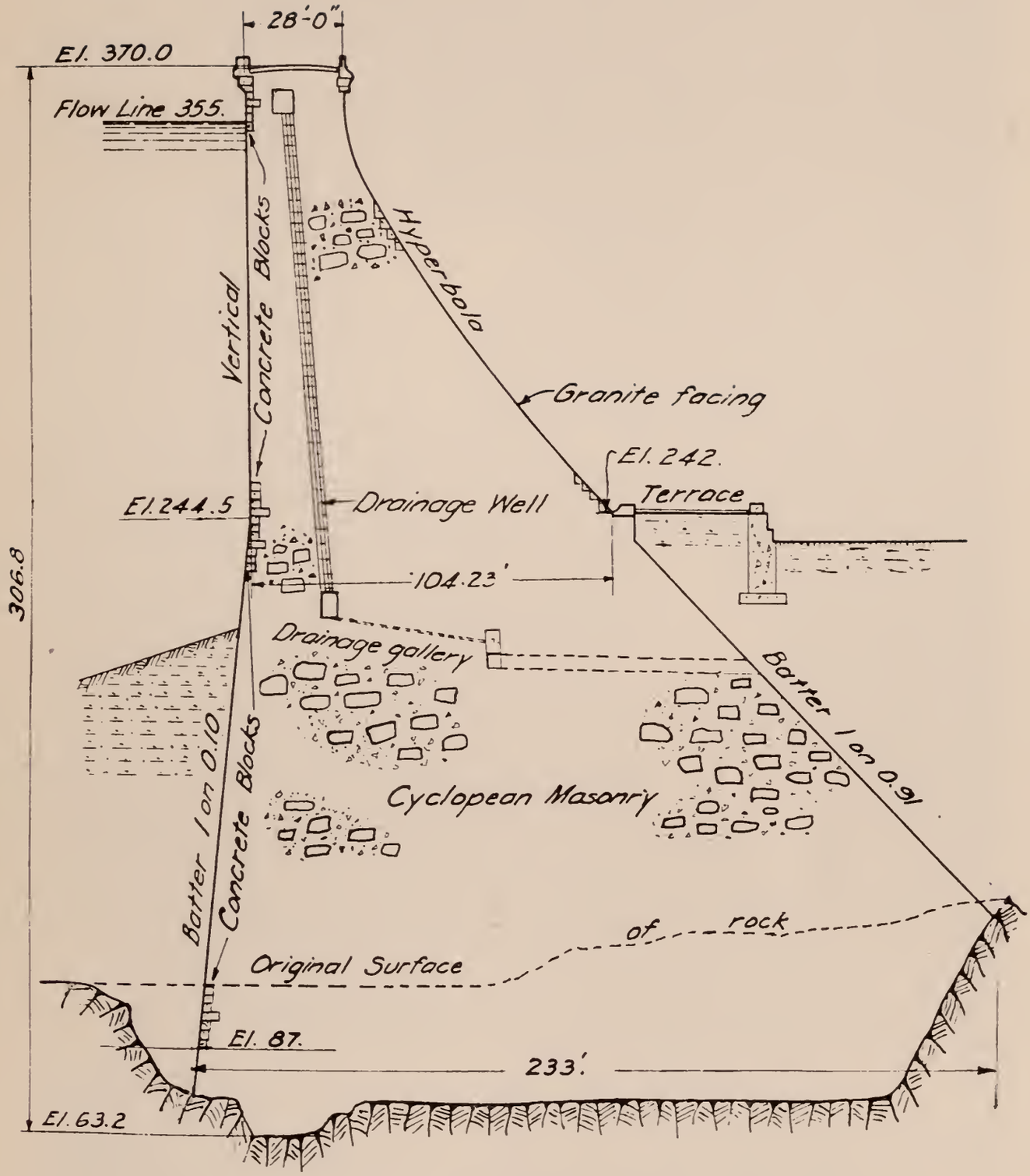
The original Kensico Dam, which was constructed across the Bronx River near the Kensico station of the Harlem Railroad, has been replaced by the present Kensico Dam. The run-off of the Bronx and Byram watersheds is merged with the Catskill water stored in Kensico Reservoir.

A line of 48-inch cast iron pipe, 15.2 miles in length, which was laid from the original Kensico Dam to the Williamsbridge distributing reservoir, is still in use. The inflow into this pipe line is now controlled at the new Kensico Dam. Williamsbridge reservoir was abandoned in 1934. The pipeline now is used for the purpose of furnishing water to municipalities along the line.

CATSKILL SYSTEM

Catskill water has its origin in the Esopus and Schoharie watersheds. These watersheds, occupying the central and eastern portions of the Catskill Mountains, collect the stream flow from the mountains of sparsely populated areas which they embrace. The Esopus watershed, draining naturally into the Hudson River, has an area of 257 square miles. The Schoharie watershed, draining to the north into the Mohawk River, has an area of 314 square miles. The combined drainage area of these two sources is therefore 571 square miles, and has a dependable yield of 525 m.g.d. when considered independently, and 555 m.g.d. when analyzed in conjunction with the Croton watershed. The rock formations included within the Esopus and the Schoharie watersheds are of sandstone and shale, and the water, in consequence, is of an unusual degree of softness. The greater part of the water from these two drainage areas is stored in the Ashokan Reservoir, the balance being held in the Schoharie Reservoir.

Schoharie Creek lies north of the Esopus, in the heart and higher sections of the Catskill Mountains. Gilboa Dam, built across the creek at Gilboa in Greene County, is located about four miles northeast from the Grand Gorge Station of the Ulster and Delaware Railroad. It is 120 miles in an air line north of the City Hall, and 35 miles west of the Hudson River. The tributaries have their source of elevations of nearly 2,000 feet in the localities of Hunter, Windham, Prattsville and Grand Gorge in Greene, Delaware and Schoharie Counties. The watershed is similar in character to the Esopus, chiefly steep mountains of shale and sandstone, which are covered with wild forest growth. These streams are flashy, there being large freshets in the spring with very little flow during the summer months. Because of this steep and rocky character, the flow in the stream is a large portion of the rainfall.



KENISCO DAM

Maximum Section

Note:—Elevations refer to mean sea level at Sandy Hook.

While the Esopus flows out of the Catskills through southerly gateway toward Kingston and the Hudson River, the Schoharie flows out through the northerly portals to the Mohawk River near Amsterdam. It lies at a sufficiently high elevation to enable the flow to be intercepted by a dam at Gilboa, reversing the direction and sending the water through an 18-mile tunnel under the intervening Shandaken Mountain Range into Esopus Creek at Allaben in Ulster County. The water thus diverted joins the water of the Esopus and finds its way for 15 miles into the Ashokan Reservoir, where it is available for delivery to the City through the main Catskill Aqueduct.

Shandaken Tunnel

The contract for the construction of the Shanaken Tunnel was awarded on November 9, 1917, for $12,138,738.

The intake is located about 3½ miles north of the Village of Prattsville. From here the tunnel extends in a general southeasterly direction until just south of the Village of Allaben, where it discharges into the Esopus Creek. The tunnel is horse-shoe shaped in section, concrete lined, with inside dimensions of 11 feet 6 inches in height by 10 feet 3 inches in width, and provided for a uniform slope of 4.4 feet per mile, except for the northerly 3½ miles, which is depressed, making this portion a pressure tunnel. Seven intermediate construction shafts were sunk, the aggregate depth of shaft being 3,238 linear feet, the maximum depth of a single shaft being 630 feet. The minimum distance between shafts is 1.3 miles, the maximum 2.7 miles. All shafts are circular and concrete lined. The upper portion of the intake shaft is so constructed that it acts as a Venturi Meter and the building over this shaft contains the control gates and the keeper's residence.

Gilboa Dam

The Gilboa Dam is composed of two parts—an overfall masonry portion about 1,300 feet in length and having a maximum height of about 160 feet with the crest at elevation 1,130 feet above sea-level, and an earth section at elevation 1,150 feet, with core-wall, approximately 1,000 feet long. Along the downstream toe of the dam there is a channel for collecting and conveying the overflow flood waters into the present channel of Schoharie Creek below the dam.

Schoharie Reservoir

The Schoharie Reservoir formed by Gilboa Dam serves both as a diverting and as a storage reservoir. It stores 19,583 million gallons, so that a large part of the storage for the Schoharie has been provided in the Ashokan

Schoharie Reservoir, showing flood flow discharging over spillway of Gilboa Dam.

Reservoir. It holds only 0.14 of the amount of the total flow of the Schoharie for an average year, while the Ashokan holds 0.98 times the flow of the Esopus Creek. The tunnel was therefore built large enough so that in times of plenty, the water can be delivered through to Ashokan at a rate of 650 million gallons a day, almost twice the normal rate of yield from Schoharie.

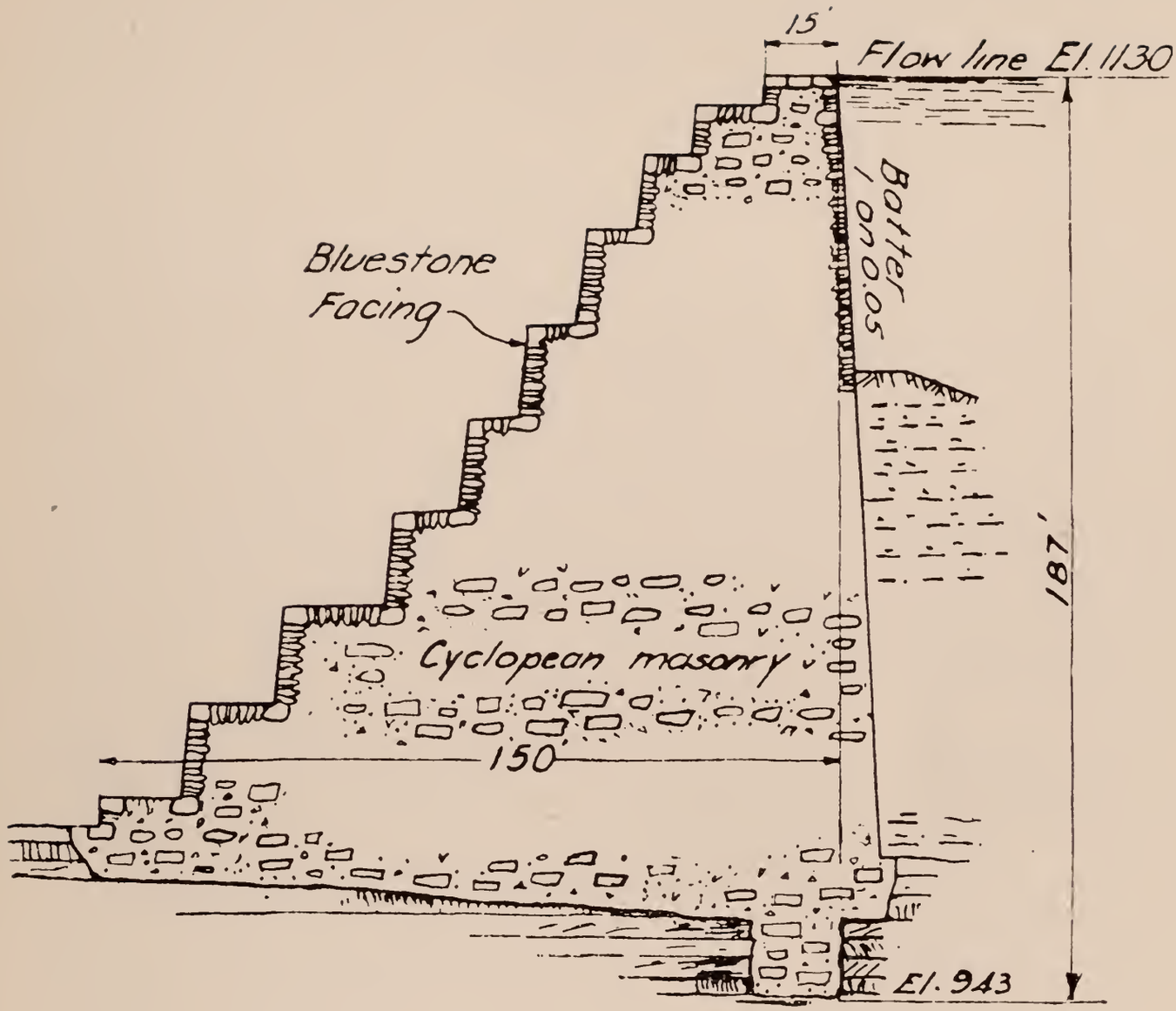
The reservoir, which has a water surface area of 1,145 acres, is approximately five miles long and about one mile in maximum width, reaching from Gilboa to Prattsville, the former being the only village disturbed. No railroad was disturbed, but the construction of 12.4 miles of highways was required to replace 13.6 miles that were abandoned. As at Ashokan, the City has acquired a marginal strip around the shore line for sanitary protection of the water.

Ashokan Reservoir

The Ashokan Reservoir is located in Ulster County, about 14 miles west from the City of Kingston. It's cost, together with that of the necessary appurtenant works, including the relocation of highways and of the Ulster and Delaware Railroad, was nearly $31,500,000. The reservoir has a water surface of 8,315 acres, and an available capacity of 127,858 millions of gallons; this capacity can be increased to 130,478 m.g. by placing flashboards on the spillway. The principal structures which form this reservoir are the Olive Bridge Dam, built of masonry, across the Esopus Creek, the earthen dikes or dams which close the gaps between the hills forming the natural walls of the reservoir, the dividing dike and weir, which separates the reservoir into two basins, and the waste weir, over which the surplus flood waters may be safely discharged. The Ashokan Reservoir is divided into two parts, which are known as the East Basin and the West Basin, the full water surface elevation of the West Basin being at 590 feet above mean tide at New York, while the East basin is at an elevation three feet lower. This division into two basins was made so as to provide greater flexibility of operation and thus at all times insure the drawing of water from that part of the reservoir in which the conditions are the most favorable.

The masonry portion of the Olive Bridge Dam is founded on solid ledge-rock and was built of cyclopean concrete faced with smoothly finished concrete blocks. At each end the masonry section is flanked by earthen dikes. The bottom and slopes of the reservoir basins were cleared of trees, brush and all other objectionable matter. This work also required the construction of 40 miles of new highway, ten new bridges, one of which has a span of 200 feet, and another a total length of 1,120 feet. The relocation of the Ulster and Delaware Railroad required the construction of 11 miles of new road-bed and track.

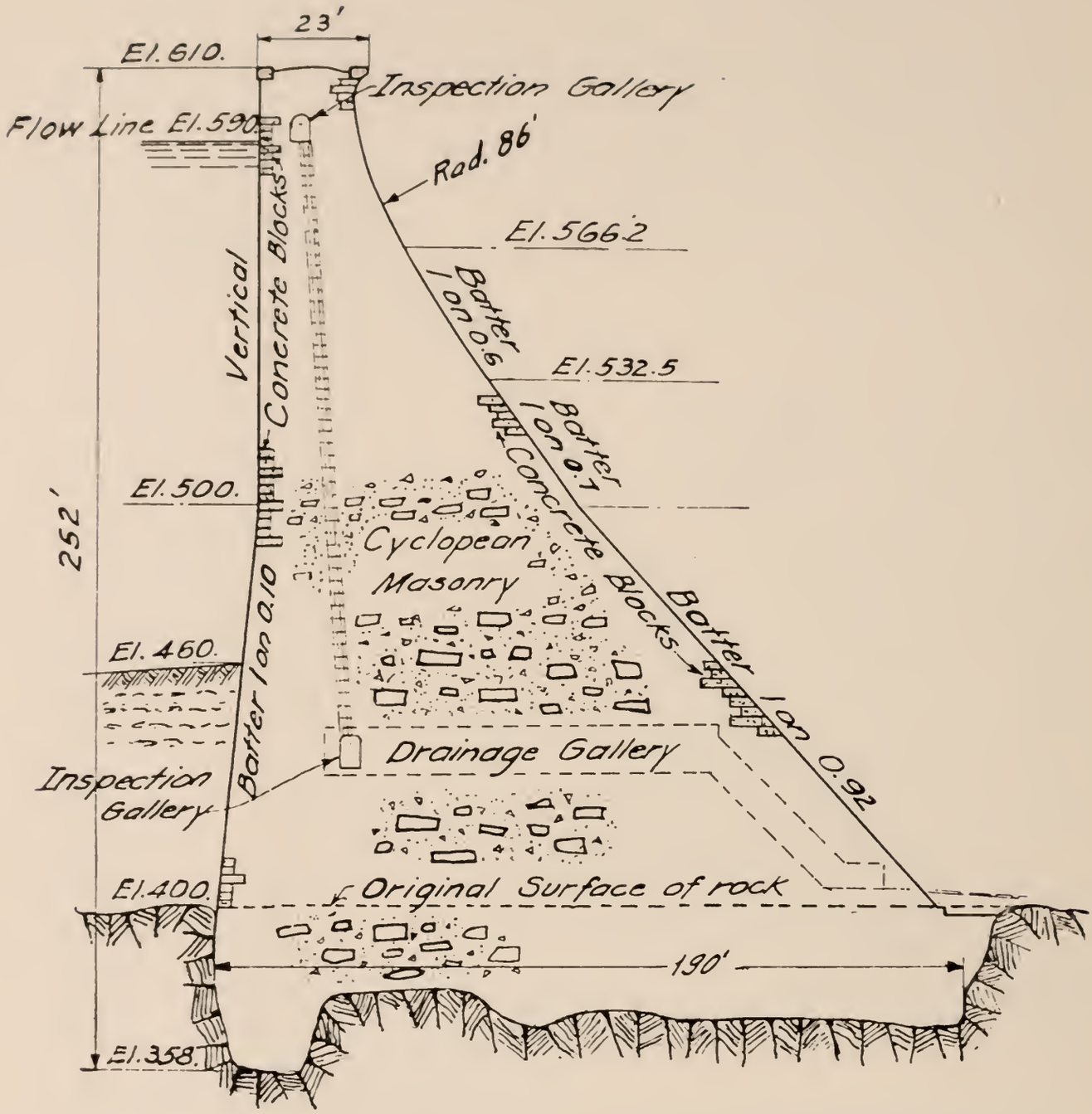
Just below the reservoir provision has been made for jetting the water into the air in fine spray, thus permitting thorough admixture of oxygen,



GILBOA DAM

Maximum Section

Note:—Elevations refer to mean sea level at Sandy Hook.



OLIVE BRIDGE DAM

Maximum Section

Note:—Elevations refer to mean sea level at Sandy Hook.

the removal of objectionable gases and the breaking down of other matter causing tastes and odors. The aerator consists of a basin approximately 250 feet by 500 feet, containing about 1,600 nozzles, through which jets of water are discharged vertically into the air.

Kensico Reservoir

The Kensico Reservoir, in Westchester County, 30 miles north from City Hall, was designed to contain sufficient Catskill water for maintaining the supply over a period of about 45 days so that the flow to the City would not be interrupted while the 75 miles of aqueduct between it and the Ashokan Reservoir were at any time out of service. This reservoir is formed by the Kensico Dam, across the valley of the Bronx River, about three miles north of White Plains, and 15 miles north of the Hillview Reservoir. Its available capacity with water at spillway elevation is 29,171 million gallons. By means of two feet of permanent flashboards on the spillway the capacity has been increased to 30,573 m.g. The surface elevation at spillway level is 355 feet and at flow line is 357 feet above mean tide at New York. The area of its water surface at elevation 355 is 2,218 acres, and the marginal protective strip around its entire circumference is generally more than 500 feet wide. The Kensico Dam contains nearly one million cubic yards of masonry—about one-third that which the Egyptians placed in the great pyramid. At the point of greatest height, it rises 307 feet above the rock foundation on which it rests. A new highway system, rendered necessary by the construction of the Kensico Reservoir, embraced the construction of 15 miles of road including a number of bridges, one of them a reinforced concrete structure of five arches, each about 127 feet long. This bridge carries the highway over an arm of the reservoir and the roadway at the center is about 107 feet above the reservoir bottom.

Catskill, Byram and Rondout waters enter the Kensico Reservoir near its upper end and are drawn from the lower end through a system of gates located in chambers about one mile north of the Kensico Dam. At this point, provision is made for controlling the rate at which the water is drawn, for screening and for sterilizing it with liquid chlorine. Here also has been provided a large aeration basin in which the water is discharged into the air through 1,599 nozzles. This operation results in thoroughly mixing the water with air and thus aiding its purification.

The Kensico Dam is a gravity masonry structure built of cyclopean masonry faced, on its upstream side, with concrete blocks and with granite masonry on its downstream face. In order to provide for the movements which result from seasonal changes of temperature, the dam is divided into sections by expansion joints spaced about 80 feet apart. Local stone was used for the facing of the dam and an effort was made to secure as rough and rugged an appearance as was consistent with the principles of the adopted design.

The Kensico Dam is located practically on the site of a small original dam which formed the old Kensico Reservoir in which were stored the waters of the Bronx and Byram Rivers. This old reservoir was very much smaller and lower than the present one, the old dam being completely submerged in the new reservoir.

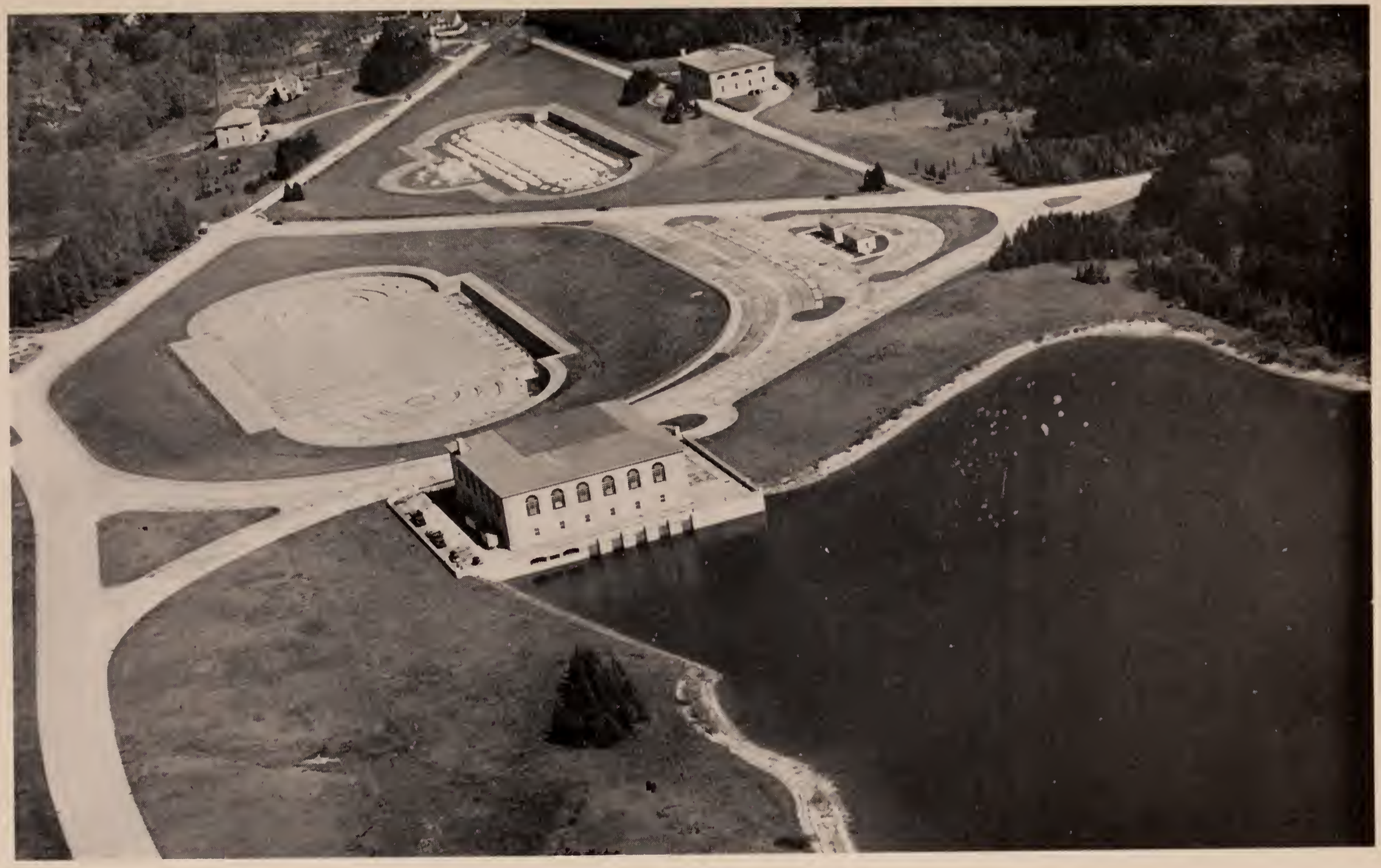
Preliminary surveys for the Kensico Reservoir were begun in May, 1906, and the contract for the construction of the dam was awarded in December, 1909, the amount of the contract being $8,006,300. It was required that the work should be entirely completed by February, 1920. Due, however, to the exceptional manner in which the work was prosecuted, the dam was completed to its full height nearly four years sooner than was thought possible when the contract was prepared.

Hillview Reservoir

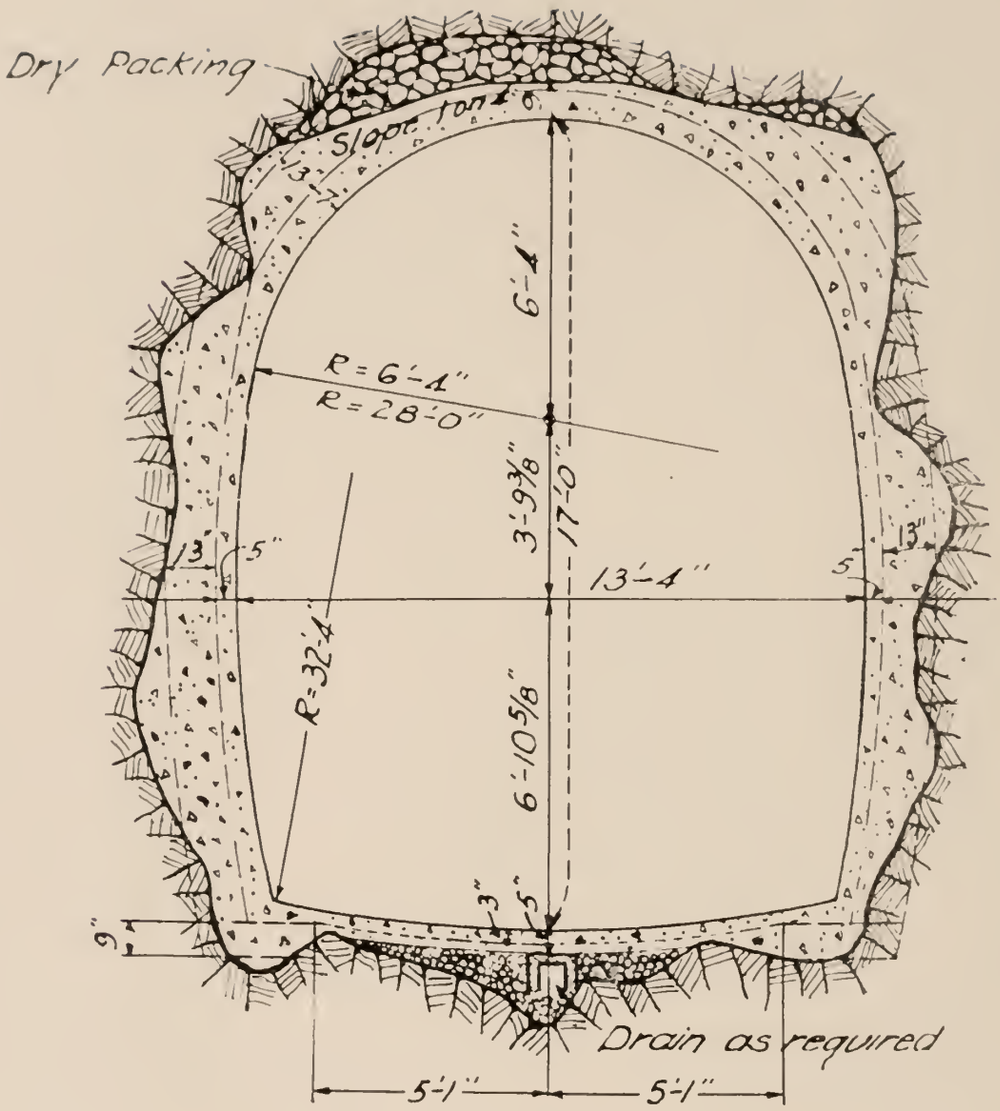
The Hillview Reservoir is located in the City of Yonkers, just north of the New York City Line, and 15 miles south of Kensico Reservoir. It is an uncovered, artificial reservoir of the earth embankment type, and is lined with concrete. It has a depth of 36½ feet and a water surface area of 90 acres. It holds 929 m.g., its function being to equalize the difference between the steady flow in the aqueduct and the use of water in the City, as it varies from hour to hour throughout the day. Its outlets are the vertical downtake shaft of the large distribution tunnel No. 1 which extends through the Bronx and Manhattan to Brooklyn and a connection to tunnel No. 2 extending through the Bronx, Queens and Brooklyn. The high pressure of the water delivered to the city through these tunnels is due to the elevation of the water surface in Hillview Reservoir, which is 295 feet above sea-level. Catskill water is delivered in the city, about 161 feet higher than Croton water. The reservoir is divided into two basins by a wall 2,740 feet long that contains the bypass aqueduct, while a bypass tunnel runs under the reservoir, so that either one or two basins may be used or, whenever required, by-passed directly into the city tunnels. The contract for its construction, including some tunnel work, was awarded in December, 1909, the cost of the work being $3,212,900. It was first filled December 29, 1915.

Silver Lake Reservoir

This uncovered distribution reservoir for Staten Island is formed by a natural depression in the high ground flanked by artificial embankments with core walls. It is about 2,400 feet long by 1,500 feet wide and 35 feet in depth and a concrete-paved dike divides the reservoir into two basins. Its total capacity is 438 m.g.d. and, when full, the water surface is 228 feet above sea-level. From a gate chamber built in this dike, reinforced concrete conduits extend to the boundary of the reservoir, where they connect to cast iron and steel mains coming from the Narrows Siphons and from the Staten Island service mains.

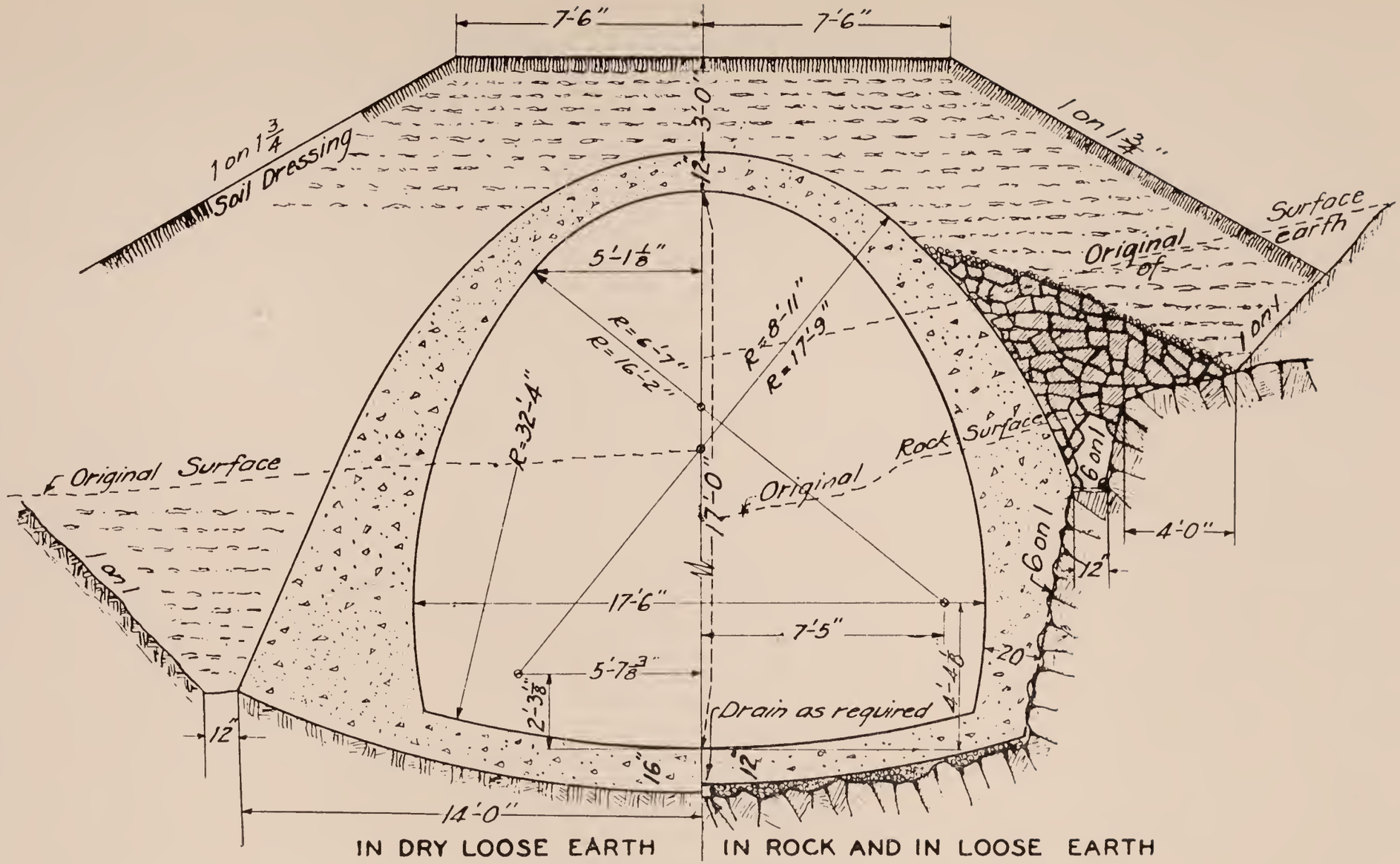


Kenisco Reservoir—New and Old Aerators—Gatehouses



CATSKILL AQUEDUCT

Grade Tunnel



IN DRY LOOSE EARTH | IN ROCK AND IN LOOSE EARTH

CATSKILL AQUEDUCT

Cut and Cover

Four distinct types of conduit or aqueduct were adopted to meet the varying physiographic features of the country traversed by the aqueduct from the Catskill mountains to the city. Where the topography and the elevation of the ground permitted, the cut-and-cover type was used. This type was the least expensive, and was built for a total of 55 miles. The construction consisted of excavating a trench, in the bottom of which a floor or invert of concrete was placed. Resting upon the sides of the invert and bonded to it, the side walls and arch of concrete, without steel reinforcement, were poured between steel forms, to the desired horse-shoe shape. From outside to outside of the masonry required a trench 28 feet wide or about as wide as between curb to curb of a New York cross-town street. Sufficient earth was taken from the trench to form a protective grassed covering of at least three feet over the concrete. That portion north of Kensico Reservoir is 17 feet high and 17 feet 6 inches wide, inside dimensions, and has generally a slope of about 1.1 feet per mile, which permits a flow of some 630 m.g.d. without putting the aqueduct under pressure. Between Kensico and Hillview Reservoirs the cross-section was enlarged to a height of 17 feet 6 inches and a width of 18 feet.

Where hills or mountains were encountered, and it would have been impracticable or uneconomical to circumvent them, tunnels were driven and lined throughout with concrete without steel reinforcement. This, the grade-tunnel type, acts similarly to the cut-and-cover type in that the water flows in it as it would in an open channel. It also is a horse-shoe shape, but of lesser dimensions and steeper slopes. There are 24 of these grade tunnels, aggregating 14 miles; they are 17 feet high and 13 feet 4 inches wide inside.

Where valleys were encountered, it was not possible to carry the aqueduct along at the natural elevation or gradient which the water would take, and in such cases, types were adopted which would withstand the internal pressure produced by placing the aqueduct below the hydraulic gradient. In the larger valleys the pressure tunnel type was used, which consisted of a circular tunnel driven deep enough below the valley bed so that the rock would withstand the internal pressure. The tunnel is connected at either end to the aqueduct by vertical circular shafts also in suitable rock. Tunnels and shafts are lined with concrete without steel reinforcement. All seams in the rock around the concrete were filled by forcing in, under pressure, thin grout made of Portland cement, fine sand and water. Drainage shafts were constructed so that each pressure tunnel can be unwatered for inspection, cleaning and repair. Besides the end and drainage shafts other shafts were sunk to aid in excavating and lining the tunnels. These construction shafts were afterwards sealed with deep concrete plugs just above the tunnel and partially refilled, near the top, with rock debris and earth supported on concrete arches across the shaft. There are seven of these pressure tunnels, totaling 17 miles, varying in diameter from 14 feet to 16 feet 7 inches.

The most important of the valleys to be crossed was that of the Hudson River, where the tunnel was driven in granite rock at a depth of 1,114 feet below sea-level. This 14-foot tunnel extends from a shaft at Storm King Mountain on the west bank to another shaft on the east side of the river at Breakneck Mountain, a distance of 3,022 feet.

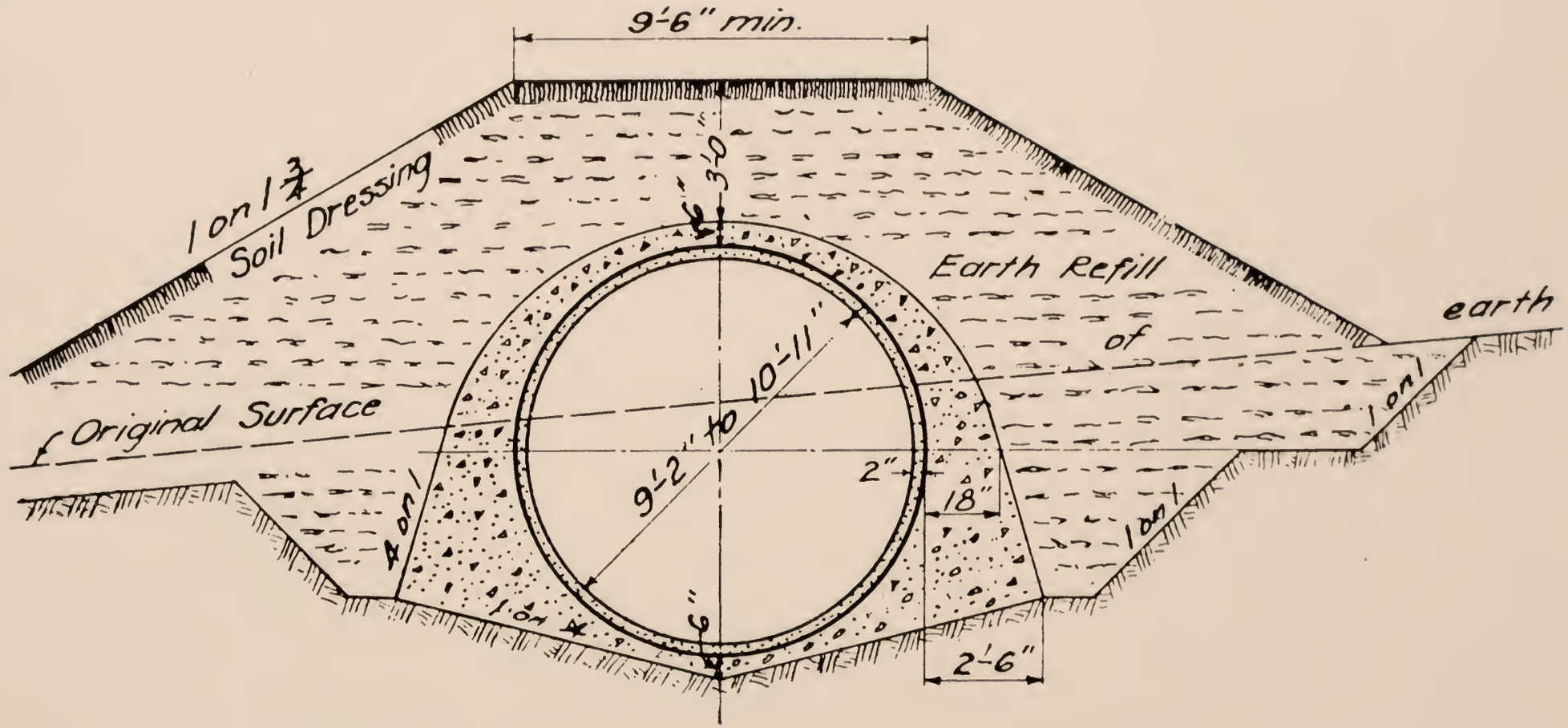
Across the smaller valleys, or where the rock was not suitable for a pressure tunnel, three parallel lines of riveted steel pipe each encased in concrete and lined with two inches of cement mortar, were laid in trenches just below the natural surface and covered with a protective grassed embankment of earth. This is known as the steel-pipe siphon type, although it is not truly a siphon but rather an inverted siphon. The pipes are from 9 to 11 feet in diameter and are made of steel plates from 7/16 to ¾ inch in thickness, riveted together. There are fourteen of these siphons, totaling six miles.

City Tunnel No. 1

From Hillview Reservoir, Catskill water is delivered into the five boroughs by a circular tunnel in solid rock, reducing in diameter from 15 feet to 14, 13, 12 and 11 feet. The total length of the tunnel is 18 miles. From two terminal shafts in Brooklyn, steel and cast iron pipe lines extend into Queens and Richmond, respectively. Two flexible jointed cast iron pipes, one 36 inches and one 42 inches in diameter, buried in trenches in the harbor bottom, have been laid across the Narrows to the Staten Island shore, where a 48-inch cast iron pipe and a 66-inch steel pipe extended to the Silver Lake Reservoir. The tunnel is at depths of 200 to 750 feet below the street surface, thus avoiding interference with streets, buildings, subways, sewers and pipes. These depths are necessary, also, to secure a substantial rock covering to withstand the bursting pressure of the water inside, and afford the requisite watertightness. The waterway of the tunnel is lined throughout with Portland cement concrete.

City Tunnel No. 1, which is one of the largest tunnels in the world for carrying water under pressure, or for any other purpose, was constructed from 25 shafts, including the downtake shaft at Hillview Reservoir, about 4,000 feet apart, located in parks and other places where they interfered very little with traffic. Through twenty-two of these shafts the water is delivered into the street mains. These connections from the tunnel to the mains are made by means of vertical riveted steel pipes (called risers) embedded in concrete in the upper part of each shaft, and lined with concrete to prevent corrosion inside. Provision is made for unwatering the tunnel, whenever necessary, for inspection, cleaning or repairs.

Unusual features in connection with the operation of the tunnel are the bronze valves in the shafts, 48 inches and 72 inches in diameter, and the section valves, 66 inches in diameter, also of bronze. The former are located



CATSKILL AQUEDUCT

Steel Pipe Siphon in Earth

Three Pipes for Each Siphon

about 100 feet below the top of sound rock and are designed to close automatically in case of serious break in the valve chamber. They can also be closed by hand from within the chambers at the shaft tops. The section valves, two in number, are located across the main tunnel, at the bottom of shafts 13 and 18, and permit the tunnel to be divided into parts and drained in sections without putting it entirely out of service.

At shaft 3, at the northerly end of Jerome Park Reservoir, connection was made to the Jerome Park Reservoir.

The cost of the portions of the Catskill Aqueduct within the city limits, including the tunnel, pipe lines, appurtenances and Silver Lake Reservoir, was $23,000,000.

City Tunnel No. 2

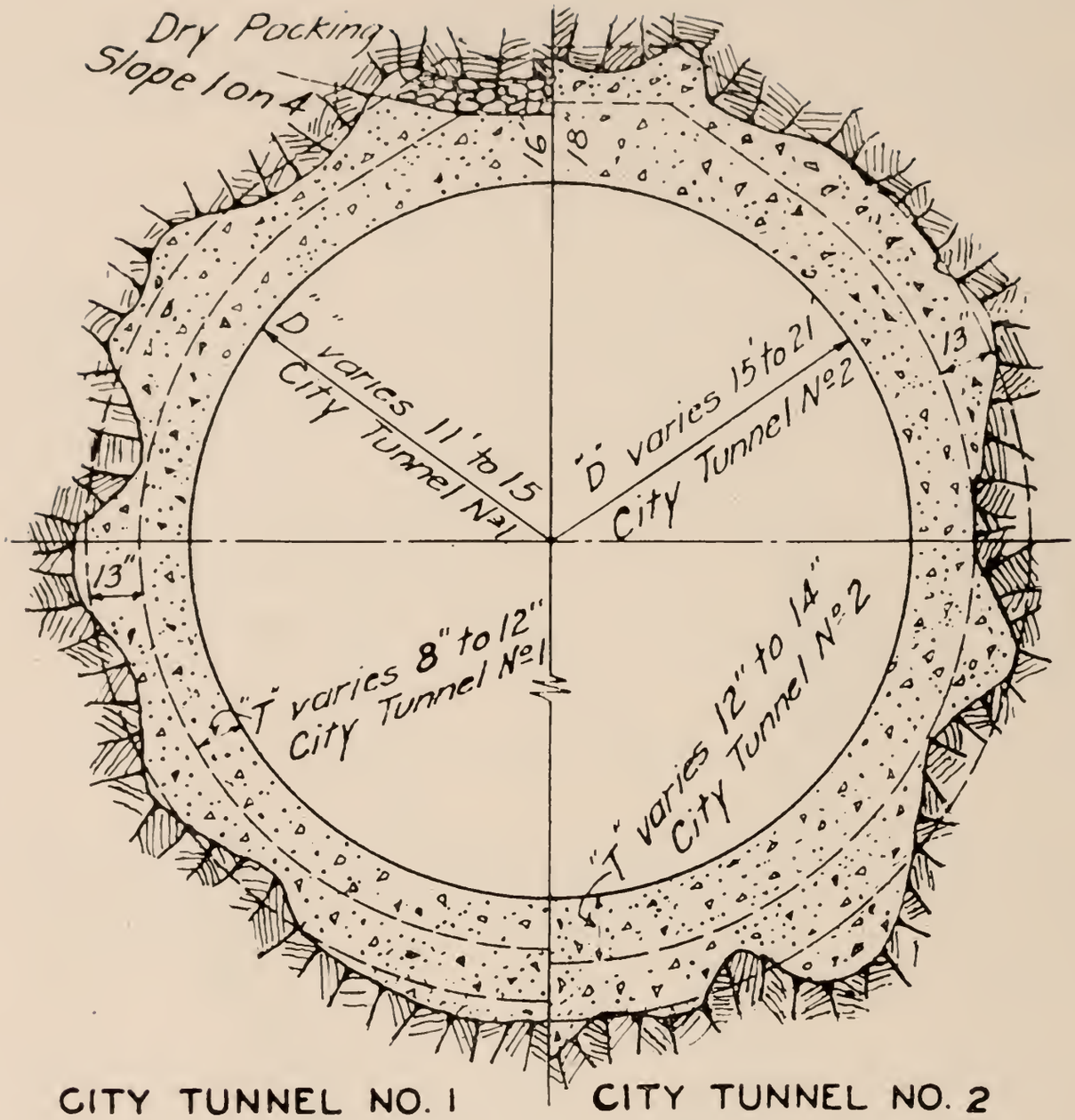
A second tunnel, 17 feet in internal diameter and 20 miles in length, known as City Tunnel No. 2, was completed and placed in service March 31, 1936. It extends from Hillview Reservoir through the Bronx, under the East River at Riker's Island, through Queens and Brooklyn, to the intersection of Hicks Street and Hamilton Avenue, connecting with the first City Tunnel at Ft. Greene Park and also at State and Nevins Streets. This tunnel not only delivers additional water, but also serves to safeguard the continuity of the supply to the various boroughs and provide better regulation of service pressures under the increased demand of recent years. It cost approximately $50,000,000.

RONDOUT CREEK SUPPLY

The first stage of the Delaware system will include reservoirs on the Neversink River as part of the Delaware River development and on Rondout Creek; together with a connecting tunnel from Neversink Reservoir to Rondout Reservoir and the main Delaware Aqueduct from Rondout Reservoir to Hillview Reservoir.

Pending the completion of the Rondout Reservoir and the installation of appurtenances in the Delaware Aqueduct, the waters of Rondout Creek were first diverted to the City in April, 1944, by means of a temporary emergency connection to the aqueduct near the site of the future Merriman Dam and by the installation of temporary control gates at the West Branch Reservoir. The character of the temporary construction limited the flow to a maximum of about 250 m.g.d., but the dependable supply of Rondout Creek in a dry period, assuming that its water were stored in West Branch Reservoir, was about 35 m.g.d.

In May, 1951, the permanent plug was installed in the diversion tunnel thus sealing the emergency connection. Thereafter, the reservoir started



CITY TUNNELS NO. 1 AND NO. 2

Pressure Tunnel

to fill and, in the early part of June, 1951, reached elevation 720, the invert elevation of the outlet channel. On June 18, 1951, the delivery of water through the permanent effluent works began.

RIDGEWOOD SYSTEM

The drainage area tributary to the Ridgewood System on Long Island extends from the borough limits of Brooklyn easterly approximately to the Suffolk County Line. The watershed is bounded on the south by the marshes and tidewaters of Jamaica and Hempstead Bays, and on the north by the ground water summit which, in a general way, follows the surface divide. The area of the watershed is about 168 square miles and, as at present developed, may be depended upon for a yield of about 70 m.g.d.

The greater part of the watershed is within the broad sandy plain which slopes gently from the hills in the central part of the island southerly to tidewater. The surface soil covering is usually light and very pervious, and ordinarily overlies coarse yellow sands and gravels of glacial origin. Below these occur gray sands and gravels separated by strata of clay of varying thickness and extent which extend to bed rock at a depth of 500 to 1,100 feet or more. Due to the porous character of the soil, practically all the rainfall is absorbed and passes underground towards the sea; a small portion appears in the form of streams where the surface of the ground dips below the water table.

That part of this watershed to the west of Rockville Centre is generally known as the old or west watershed; the sources of supply are Smith's Pond, Valley Stream Pond, Hempstead Pond, Hempstead Storage Reservoir, and ten driven well pumping plants. Smith's Pond and Valley Stream Pond are used only in emergencies. The supply is collected by a brick conduit of horse-shoe section, about 12 miles long, having a slope of approximately six inches to the mile, extending from Hempstead Pond to the Ridgewood Pumping Station, where all the water is pumped into the Ridgewood Distributing Reservoir; a 72-inch steel pipe line extending the entire length of the watershed was formerly utilized for conveying the delivery of some of the driven well plants to the Ridgewood Pumping Station, but in 1925 the section extending westerly from the Milburn Pumping Station was placed under the Brooklyn distribution pressure, and delivered water to Brooklyn, the Rockaways and other sections of Queens Borough. The brick conduit has a gradually increasing section towards the west, the carrying capacity of the maximum section being 76 m.g.d. The other ponds on this shed (Baisley's, Springfield, Simonson's, Clear Stream, and Watts), the surface waters of which were originally pumped into the main conduit or delivered into same by gravity through branch brick conduits of circular cross-section, have been abandoned, on account of pollution due to increase in population.

City Tunnel No. 2, 17 feet in diameter, during construction, showing the concrete lining, with the arch still to be placed in the foreground.

The new watershed, adjoining the old on the east, has for its sources of supply five ponds—Milburn, East Meadow, Newbridge, Wantagh and Massapequa—five driven well plants, and two infiltration galleries. The Milburn and Newbridge Ponds have been abandoned as direct sources of supply. The supply is collected and carried by gravity to the pump well of the Milburn Pumping Station through a brick conduit a little over 7¼ miles long, extending from Massapequa westward to the Milburn Pumping Station, and having a grade of one in ten thousand.

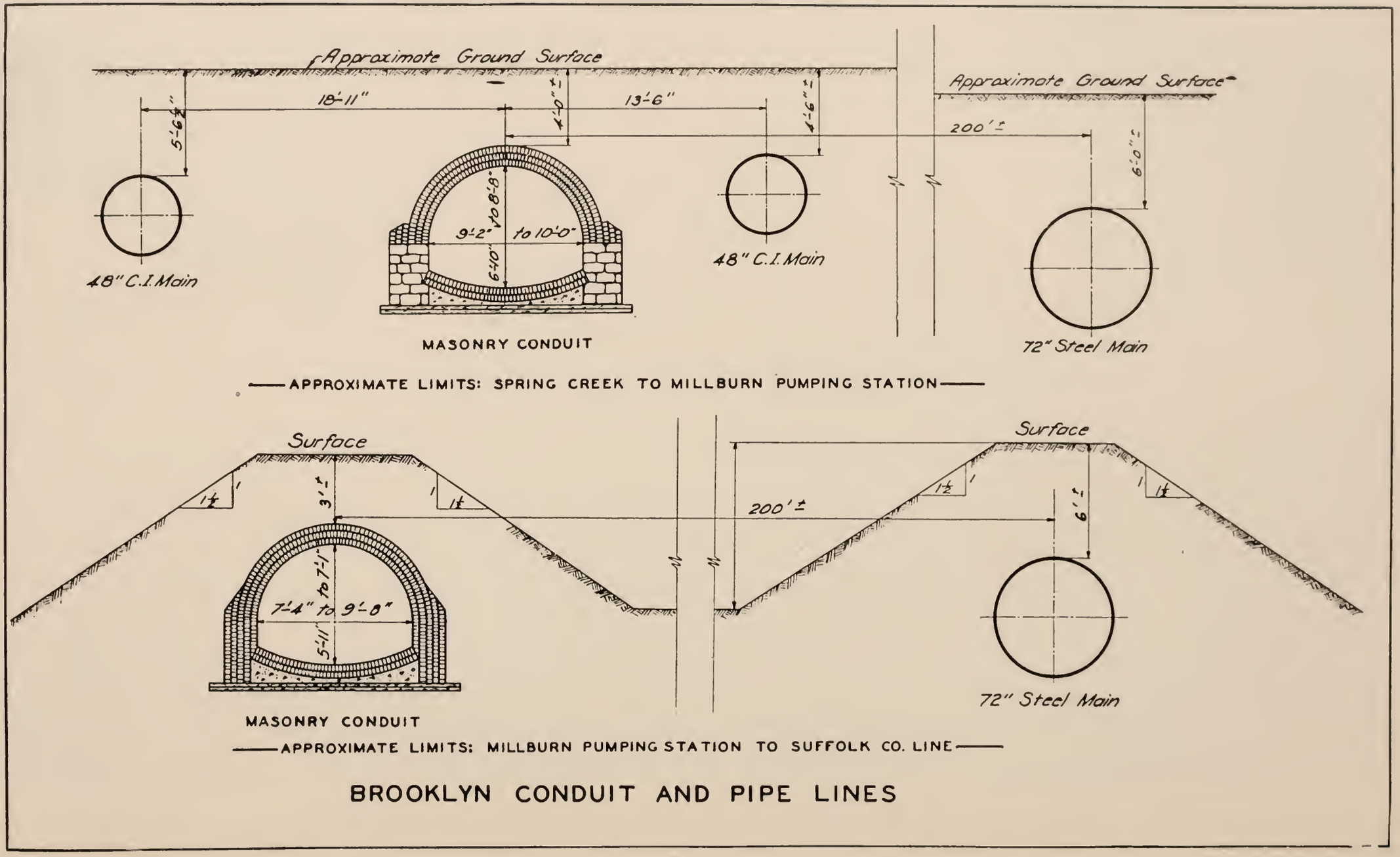
This conduit is of horse-shoe section 5 feet, 11 inches high, and 7 feet, 4 inches wide at its easterly or Massepequa end, with a capacity of 40 m.g.d. The size increases at each supply pond and at its westerly end at Milburn Pumping Station the section is 6 feet, 11 inches high by 9 feet, 4 inches wide, with a capacity of 59 m.g.d.

The ponds in the east watershed discharge into the conduit which they immediately adjoin on the north, through short sluice-ways; the driven well and infiltration gallery pumping plants are just south of the conduit and discharge into same, or into the 72-inch steel pipe line, through short delivery mains. The two infiltration galleries aggregate six miles in length and yield 30-40 m.g.d.; they consist of vitrified tile sewer pipe laid with open joints surrounded with gravel, from 10 to 15 feet below the normal ground water level.

All the water from the east watershed is pumped at the Milburn Pumping Station where part of the supply is delivered to the 72-inch steel pipe line before mentioned, and part to three 48-inch cast iron lines which lead to Ridgewood Pumping Station, where it is repumped. Two of these 48-inch lines formerly extended directly to Ridgewood Pumping Station, being reinforced at Spring Creek by another 48-inch main. In 1927 the three 48-inch pipe lines that extend from Spring Creek to Ridgewood Pumping Station were replaced by a 72-inch reinforced concrete pipe which was made necessary by the construction of Sunrise Highway. These mains adjoin and are parallel to the old brick conduit for the entire distance west of Smith's Pond. The third 48-inch pipe from Milburn reduces to 36 inches at the efflux chamber of the abandoned Milburn Reservoir and terminates at the old brick conduit at Smith's Pond; by this means the old conduit can be partly utilized for conveying some of the yield of the new watershed.

QUEENS SYSTEM

Local municipal sources of supply within the limits of the Borough of Queens are derived from driven wells. All of the local sources in Queens must be pumped, and the City maintains one electric pumping station, and seven individual electrically operated well stations for this purpose. The Queens System yields about 10 m.g.d. and is used, as needed, to supplement the Catskill supply.



BROOKLYN CONDUIT AND PIPE LINES

RICHMOND SYSTEM

The Richmond System consists of two driven well plants located in different parts of the borough. One of these plants consists of five stations driven electrically, each pumping its output into the distribution system. The Richmond System yields about 5 m.g.d. Two stations, electrically operated, are used for boosting Catskill water to the high and intermediate services.

HUDSON RIVER PUMPING PLANT

This plant was constructed in 1950 by the Board of Water Supply as an emergency measure to cope with water shortages that might occur prior to the completion of the present Delaware Development. The station is capable of pumping 100 million gallons of water daily from the Hudson River near Chelsea, N. Y. into Shaft 6 of the Delaware Aqueduct, against a head of 600 feet.

The plant, except for test-runs, is to be used at times of extreme emergencies only, when all of the other sources of supply are insufficient to meet the demands in the City. The New York State Water Power and Control Commission in permitting the City to construct the station, specified that it must be demolished on or before January 1, 1957, or upon completion of the current Delaware Development, unless permission is granted to continue the station beyond that date.

UTILIZATION OF THE PRESENT SOURCES OF WATER SUPPLY

As previously stated, the city now has available the Catskill and Rondout supplies and, of its older sources, the Croton, Ridgewood, Queens and Richmond Systems.

The sources of supply for the municipal system, and the amounts each can safely furnish, are as follows:

Sources of Water Supply	Tributary watershed area, in Sq. Miles	Quantity estimated to be continuously available based on the driest period of record with a reserve of 25% of total available storage	
Schoharie Watershed	314	885 m.g.d.	
Esopus Watershed	257		
Croton Watershed	375		
Bronx and Byram Watersheds	22	10 "	
Ridgewood	Indeterminate	80 "	
Queens Borough	"		
Richmond Borough	"	5 "	
Rondout Watershed	95	120 "	
Total			1100 m.g.d.
PROPOSED DEVELOPMENTS			
East Branch Watershed	372	335 m.g.d.	
Neversink Watershed	93	105 "	
Total			440 m.g.d.

All of the sources of supply furnish a safe and palatable water. Therefore, when it becomes necessary to furnish additional amounts of water, due to increase in consumption, the available sources are drawn upon in the order of their cost of operation.

The waters from the Catskill, Bronx and Byram, Rondout and Croton West Branch sources are intermingled in Kensico Reservoir, from which the water flows through the Catskill and Delaware Aqueducts to Hillview Reservoir. From Hillview Reservoir the two City Tunnels deliver the water to the five boroughs.

Because of its greater pressure it is the least expensive of the supplies to operate. It is a gravity supply and only needs to be pumped to small areas of high elevation. Therefore this supply is generally used to the full capacity of the Catskill Aqueduct.

Croton water also flows to the city by gravity, but it is delivered to the Boroughs of Manhattan and the Bronx at an elevation which is much lower than the Catskill supply, and the amount that can be used without pumping is limited to the demands in portions of Manhattan and the Bronx, lying in general, below elevation 40 feet. The demand in these portions averages about 110 m.g.d. All Croton water that is used on higher ground must be pumped. The department maintains one steam, two hydraulic and four electrically operated pumping stations for this purpose, having a combined capacity of about 230 m.g.d.

The city maintains all of its old sources of supply and retains a reserve force to permit the prompt operation of some of the stations in case of emergency. The pumped supplies, being the most expensive to use, are drawn upon after the gravity supplies have been utilized to their greatest permissible extent.

QUALITY OF THE WATER

A great safeguard which the City possesses is the extent of storage on its up-state watersheds; the long period of sedimentation afforded by the large storage reservoirs serves to reduce the bacterial content and turbidity. For the sanitary protection of these reservoirs the City acquired a marginal strip averaging 1,000 feet in width around the Schoharie and Ashokan Reservoirs, 500 feet around Kensico Reservoir and 300 feet around the Croton Reservoirs and along the streams emptying into them.

An inspectional force under a sanitary expert patrols the watersheds to detect and abate sources of contamination and to insure compliance with the department's sanitary rules and regulations.

The Ashokan Aerator. The building is the Ashokan screen chamber where the Catskill Aqueduct begins.

All water is treated with chlorine. The Croton, New Aqueduct, is so treated at the Croton Lake Gatehouse, and at Dunwoodie in Yonkers, the Old Aqueduct at Dunwoodie and the 135th Street Gatehouse. On the Croton watershed the Peach Lake effluent and Tonnetta Brook are treated at Brewster, Katonah Brook at Katonah, Kisco River at Mt. Kisco, St. Mary's Brook at Bedford Hills, Kilday Brook at Bedford and the outlet of Lake Gleneida at Carmel. The Catskill is treated as it leaves the Ashokan Reservoir, at Kensico Reservoir and again at the Hillview Reservoir downtake chambers. The supply from Rondout Creek is chlorinated, by a temporary plant, at the Kensico Reservoir influent chamber. The Long Island supply is treated at Milburn Pumping Station, Ridgewood Pumping Station, Smith Pond, and the wells at Hook Creek, Clear Stream and Watts Pond. The Brooklyn, Queens and Richmond driven well stations are also chlorinated. There are altogether some 40 city-owned chlorinating plants and 80 privately operated plants at which chlorine may be applied to the water supplied to the city consumer.

A very high degree of purification has been uniformly secured at all of these plants. The typhoid fever death rate has been progressively reduced, being but 0.01 per 100,000 of population in 1950, nor were these deaths due to impure water, but rather to other causes, or to disease contracted outside of the city limits.

Catskill water is aerated to free it from gases which produce unpleasant odor or taste. These aerators, each consisting of some 1,600 nozzles, are installed at the Ashokan and Kensico Reservoirs.

Microscopic organisms which develop in the reservoirs and at times impart an unpleasant taste and odor to the water, are destroyed by treatment with copper sulphate and by chlorine dosage.

To reduce the turbidity of the Catskill supply when necesary, alum is added at a coagulating plant at Pleasantville, about 30 minutes flow above the influent to Kenisco Reservoir; then lime is added at the lime treatment plant close to the Kensico Reservoir Influent and the floc, which entangles the particles causing turbidity, settles out of Kensico Reservoir before the water reaches the effluent gate house.

To safeguard the City's water supply the Department operates the sewage disposal plants of the following villages: Brewster and Lake Mahopac in Putnam County, Mt. Kisco in Westchester County, Chichester and Pine Hill in Ulster County, Tannersville in Greene County and Grand Gorge in Delaware County; it makes periodic tests to control the operation of the disposal plants of private institutions in the watershed and passes upon the plans for all private disposal plants.

Open gravity type rapid sand filters are used to remove iron from the well waters at Springfield and Jameco Pumping Stations. Iron is removed by means of pressure filters at the Flushing Station. The private companies operate two gravity and three pressure filters for iron removal from well waters.

The reforestations started in the Croton watershed in 1912 by planting three-and four-year-old evergreen transplants along the shores of reservoirs and adjacent to public roads has been continued in this as well as in the Catskill, Bronx and Byram watersheds. These trees, in addition to beautifying the general landscape, provide a dust screen, prevent erosion and serve to decrease turbidity.

New mains are sterilized and are not placed into service until laboratory analyses show them to be clean. Cross-connections, or connections from any other source of supply to any piping supplied by city water, are forbidden.

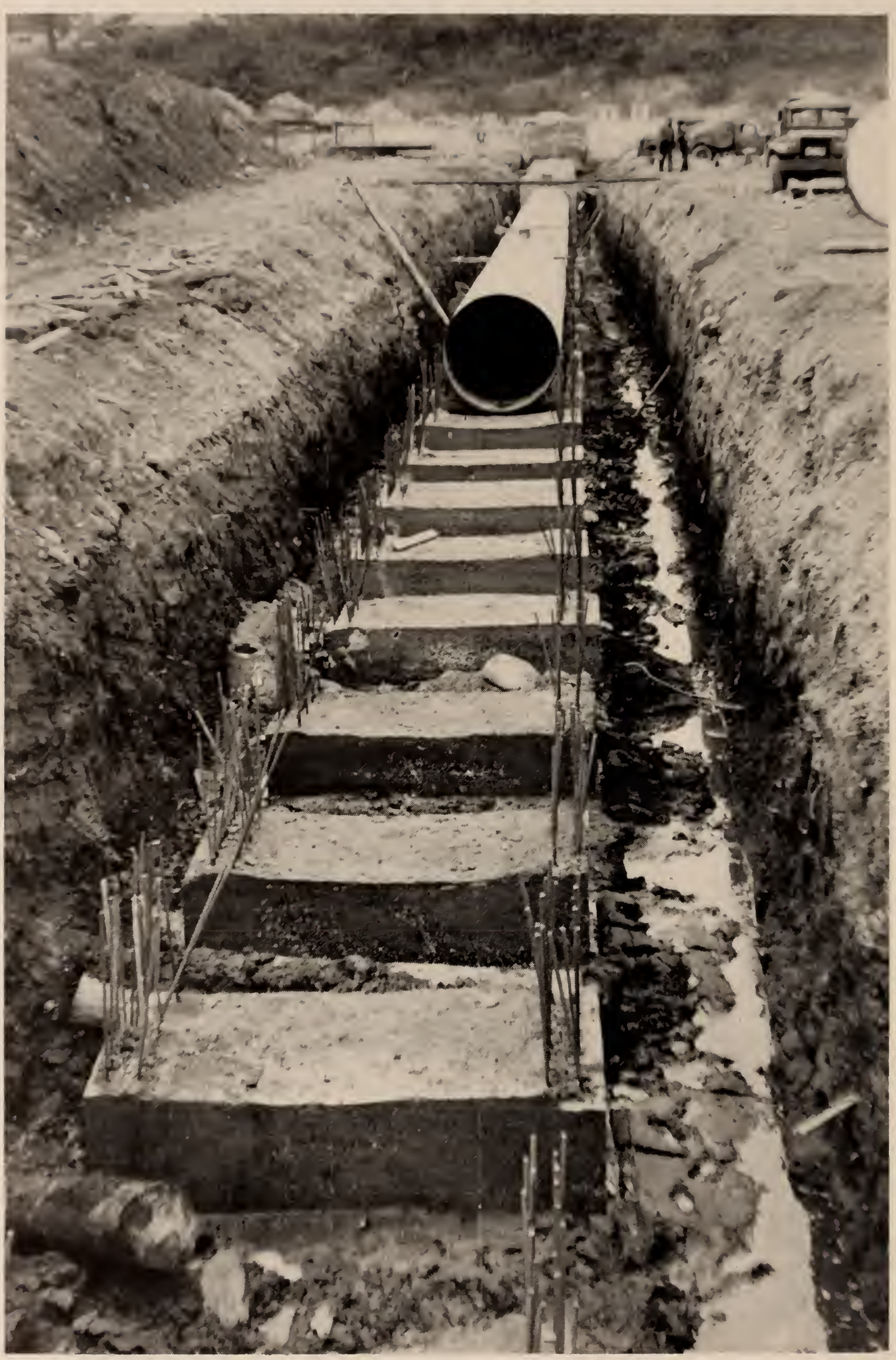
At three laboratories, daily bacteriological examinations are made of samples of water taken at different points. Additional samples from sources of supply which do not require daily investigation result in laboratories examining over 32,500 samples during the year. In case any portion of the supply is shown to be unsatisfactory, either its use is discontinued, or the objectionable conditions are ascertained and remedied. The laboratories are well equipped with modern apparatus and are located respectively in Brooklyn; at Mount Kisco, Croton watershed; and at the Ashokan gatehouse, Catskill watershed.

DISTRIBUTION SYSTEMS

The distribution systems in the various boroughs are divided into independent services or zones, with three or more such zones in each borough. The areas of these zones are determined chiefly by the local topography. The ground elevation in the city varies from a few feet above sea level along the water front to 430 feet at Todt Hill in the Borough of Richmond; this, incidentally, is the highest point on the Altantic coast south of Maine. The highest ground elevations in the other boroughs are: Manhattan, 267 feet; Bronx, 284 feet; Brooklyn, 210 feet; and Queens, 266 feet above tide.

The average pressure at hydrants in the different service zones in the city ranges from 35 pounds per square inch in the Manhattan low service to 80 pounds per square inch in the Richmond high service area. The average pressure in the city is approximately 55 pounds per square inch, which is adequate for supplying water to the top floor of an eight-story building.

There are five (5) distributing reservoirs in the municipal system which provide storage to meet the hourly fluctuations in the regular demand for water throughout the city, as well as any sudden increase in draft that might arise from fire or other emergencies.



72" Steel Main—Flushing Meadow, Queens

The Hillview Reservoir, which is immediately north of the city line in Yonkers, and the Silver Lake Reservoir in the Borough of Richmond, have already been described as part of the Catskill system. The remaining three distributing reservoirs are the Jerome Park Reservoir in the Bronx, the Central Park Reservoir in Manhattan and the Ridgewood Reservoir in Brooklyn.

Jerome Park Reservoir in the Borough of the Bronx is an uncovered concrete lined basin formed by earthen embankments and natural ground, excepting the easterly side which is a masonry structure originally intended for a division wall to divide the reservoir into the east and west basin, the former never having been built. The "division wall" carries the Old Croton Aqueduct throughout its entire length as well as a branch of the New Croton Aqueduct to its southerly and where it discharges into the reservoir. The main new Croton Aqueduct passes under the reservoir about 100 feet below the surface and continues to the 135th Street gatehouse in Manhattan. The flow into and out of the reservoir is controlled by four gate chambers.

The gatehouse at the northerly end of the reservoir at the division wall controls the flow through a short stretch of tunnel leading to Shaft 3 of City Tunnel No. 1 of the Catskill System. The arrangement of piping in the chamber permits either the delivery of Catskill water into the reservoir or the pumping of Croton water from the Reservoir into City Tunnel No. 1. This pumping is by means of three electrically driven pumps installed in the shaft chamber, known as the Mosholu Parkway Pumping Station, with each pump of a capacity of 20 m.g.d.

The present reservoir with a capacity of approximately 800 m.g. at the spillway elevation of 135.50 feet was filled in 1905. Work at the east basin was suspended pending decision of the question of filtering the Croton supply. The filtration plant was to have occupied the area intended for the east basin but in 1912 the entire project was abandoned and the lands were released by the department in 1917. The site is now occupied by educational buildings, subway yard and other structures.

The new Central Park Reservoir in Manhattan is an open basin completed in 1862 when the Old Croton Aqueduct was the only aqueduct supplying water to the City of New York. It was constructed "to keep an available supply of water in case a break should occur in the aqueduct making it necessary to shut off the water for examination and repairs." At the present time it still receives water from the Old Croton Aqueduct and in addition it is supplied from the New Croton Aqueduct by means of 3 48-inch pipe lines from the 135th Street gatehouse. The reservoir is now being used as an equalizing and distributing reservoir for the low service areas in Manhattan and for furnishing water to the Central Park and 40th Street Pumping Stations; it holds 1018 million gallons at the spillway elevation of 119.40 feet.

The entire supply of Croton water delivered to the city through the

Croton Aqueducts is distributed from Jerome Park Reservoir in the Bronx and from Central Park Reservoir and the 135th Street Station gatehouse in Manhattan. A number of widely scattered areas of low elevation, generally below 40 feet, are supplied by gravity from these distributing points. This gravity supply amounts to about one-third of the total available Croton supply; the remainder of the Croton supply is pumped at the 98th Street, Central Park, 179th Street and 40th Street Pumping Stations in Manhattan and at the Mosholu Parkway, Jerome Avenue and Crotona Parkway Pumping Stations in the Bronx to reach the higher elevations.

The Catskill supply, which extends to all five boroughs, is distributed from the riser shafts of City Tunnels No. 1 and No. 2. The Catskill gradients are sufficiently high to reach all but the highest elevations in Manhattan, Bronx and Richmond. Catskill water is pumped at the 179th Street Pumping Station in Manhattan, at the Riverdale Station in the Bronx and at the Clove Lake Station in Richmond. The pressures are regulated at the distributing points if necessary, to maintain the desired pressures in the different service zones. In the services supplied with both Catskill and water pumped from some other source of supply, the Catskill pressure is regulated to accommodate the gradient of the pumped supply.

The supplies from the Ridgewood, Brooklyn and Queens Borough systems which are obtained chiefly from sub-surface sources, must be pumped. Part of the supply is delivered directly into the Ridgewood Reservoir, which also receives water from the Catskill System and is used as an equalizing reservoir for the Brooklyn low service. This reservoir, located on Cypress Hills, consists of three basins with an aggregate capacity of 302 million gallons at high water elevation of 172.54 feet. Each basin has a puddle bottom and sloping sides paved with stones. The first two basins of half the total capacity were completed in 1858 and the third in 1891.

The pipes used in the City for distributing the water supply range in size from 4 inches to 72 inches. At the close of 1951 the total length of steel and cast iron pipe in service amounted to 5,412 miles as given in detail in one of the attached tables. With the development of improved protective coatings for steel pipe and in order to reduce the considerable damage from floods resulting from breaks in cast iron trunk mains, the department in 1926 adopted the policy of installing water mains 30-inch and larger of steel with a minimum thickness of plate of ½ inch.

The minimum size of cast iron pipe used for extensions is 12 inches in congested sections and 8 inches elsewhere. To overcome the excessive tuberculation caused by the soft and "active" Catskill water, all cast iron pipe since 1929 has been furnished with a ⅛ inch interior cement mortar lining coated with a cold application of asphalt paint. The asphalt serves to retard or entirely prevent the leaching of the cement, without effect either upon the taste or odor of the water.

Gate valves are located near street intersections and the arrangement provides in general for convenient shut-off sections.

A standard double-disc valve, adopted in 1914 and opening clockwise, predominates. The valves in the Catskill shafts are operated by small water motors; some of the large control valves in the gatehouses of the distributing reservoirs are electrically or hydraulically operated. At the close of 1951, a total of 153,050 valves, ranging in size from 2 inches to 48 inches were in use.

Hydrants are of the double nozzle type, and 80,584 of the 83,515 in use at the end of 1951 were the New York standard, which has a 6 inch valve connection with the main and a 7½ inch barrel with one 2½ inch one 4½ inch outlet.

Eighteen repair companies are maintained for keeping the valves and hydrants in good operating condition, to repair breaks in water mains, and stop reported leaks such as may be caused by loose joints, abandoned taps, service pipes, hydrants, and valves. During the past ten years, an average of over 20,000 leaks in the distribution system were stopped annually by these repair companies. In each borough, an emergency force of, at least, one gang is on duty at all hours.

The department is authorized by statute to determine the locations not only of water mains, but of all other sub-surface structures (such as electrical conduits, gas mains, steam pipes, and pneumatic tubes) except sewers and rapid transit tunnels. This enables the department to provide for ready access to water mains for repairs and connections, to protect the water mains from excessive loads of other structures crossing them, and to ensure the reservation of adequate space for the installation of future mains.

HIGH PRESSURE FIRE SERVICE

The Department of Water Supply, Gas and Electricity also operates in portions of Manhattan and Brooklyn and at Coney Island a special service by means of a High Pressure Fire System to which no connections to buildings are permitted and which is used exclusively for fire fighting purposes.

The Manhattan system was first used in July, 1908. It covers approximately 3700 acres in lower Manhattan, where it protects the valuable business and industrial centers. The Brooklyn system, which was placed in service in November, 1908, protects the important manufacturing, business and water front section lying between 39th Street and the Navy Yard, covering approximately 3100 acres. The Coney Island system covers 608 acres.

One of the Manhattan pumping stations is at Oliver and South Streets and the other at Ganesvoort and West Streets, each with a capacity of 18,000 gallons per minute at 300 lbs. per sq. inch, with increased capacities at lower

pressures. There are two similar stations in Brooklyn, located respectively at Furman and Joralemon Streets and at Willoughby and St. Edwards Streets, the former having a capacity of 15,000 g.p.m. and the latter 9,000 g.p.m. at 300 lbs. pressure per sq. inch. The Coney Island station is at Neptune Avenue and West 23rd Street; the capacity of this station is 13,500 g.p.m. at 200 lbs. pressure per sq. inch.

The length of the high pressure fire service mains in Manhattan is 127 miles, 8 inches to 24 inches in diameter, and in Brooklyn, 50 miles, 8 inches to 20 inches in diameter. The lower east side of the Manhattan System is arranged so that it may be divided instantaneously into two independent systems; when so divided, each system serves the alternate cross streets and the alternate street running north and south. In case of a break only one system would be affected, as the other would be shut off from it immediately by valves electrically operated from the pumping stations.

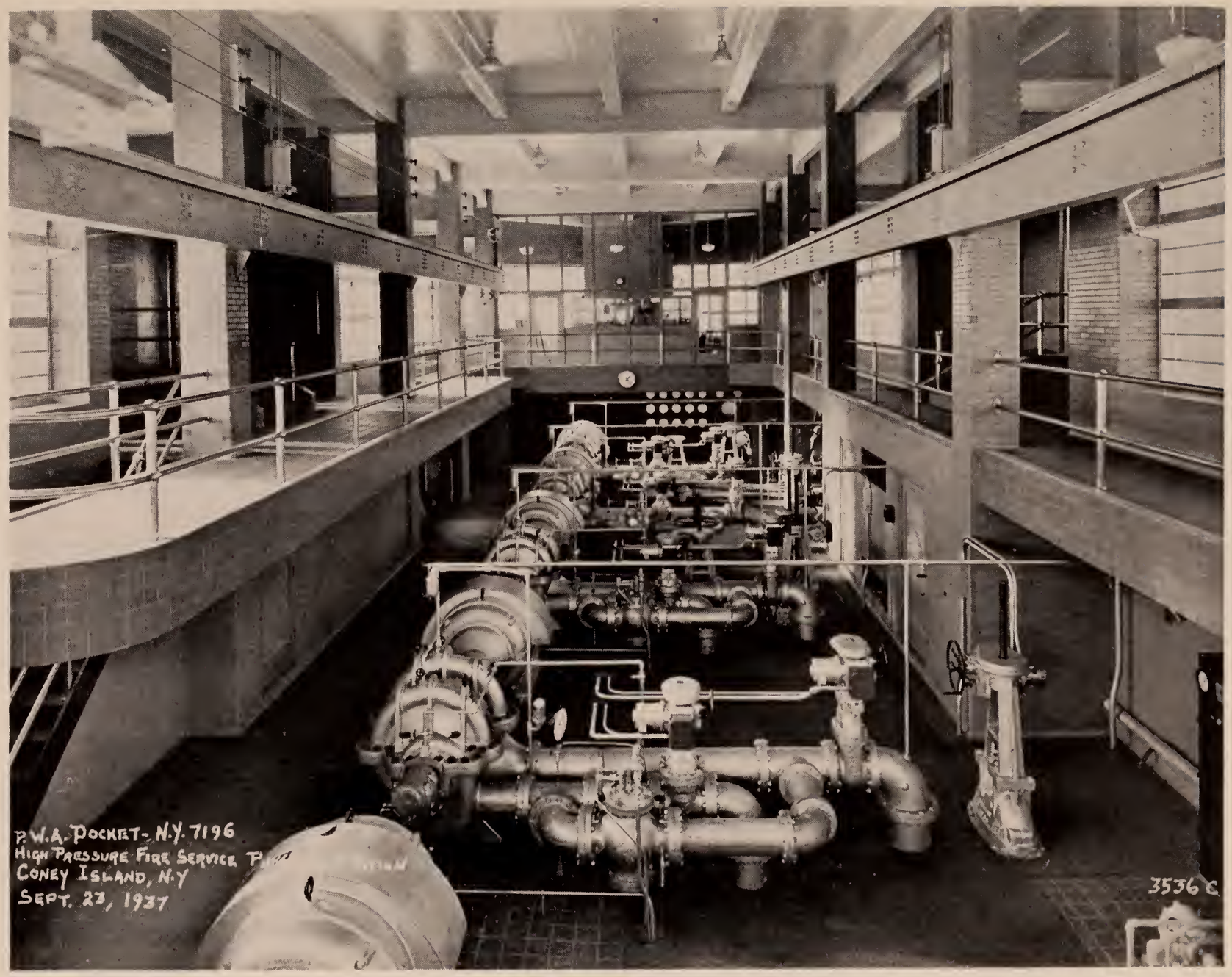
The high pressure fire service stations are operated through high-voltage current furnished by the Consolidated Edison Company. Upon the request of the Fire Department, the pressure can be increased to a maximum of 300 pounds per square inch. At Coney Island, the limit of pressure is 200 pounds per square inch. When an alarm is received, pressure is furnished throughout each of the systems within the period of a minute.

Salt water can be used in this system, but its use is not contemplated unless the fresh water supply were to fail, which has never yet occurred.

CONSUMPTION AND WASTE OF WATER

The daily aggregate consumption of water within Greater New York averaged 1,042.1 m.g.d. during 1951, including the 38.9 m.g.d. furnished by the private water companies of Queens. This corresponded to a per capita consumption of 131.1 gallons per day. In addition to the foregoing, the municipality supplied 28.1 m.g.d. to communities outside of the city.

The Department has a force of specially trained men, under engineering supervision, engaged in locating the sources of troublesome leaks which find their way, by diverse subterranean routes, into basements, subways, electric conduits etc. This force operates in the Boroughs of Manhattan and the Bronx, where rock fill exists under many streets through which water from leaks readily escapes. The average leakage located and stopped yearly has been approximately 10 m.g.d. In addition, a force of four field parties is assigned to conduct underground surveys in the Boroughs of Manhattan and the Bronx. Their duties are to test all service pipes, valves, hydrants, mains and other water supply appurtenances for the purpose of detecting and locating unknown leaks. The force covers the two boroughs biannually and the leaks detected and repaired have resulted in an average savings of about 20 m.g.d.



Pump room of the Coney Island High Pressure Fire Service Station.

PRIVATE WATER COMPANIES

Some 450,000 citizens residing in Queens and consuming about 40 m.g.d. are still dependent upon private water companies for water. An additional 350,000 persons in Brooklyn, consuming about 29 m.g.d., were, until July 1, 1947, receiving their water from the New York Water Service Corporation (Flatbush Plant). All of these companies obtained their supplies from drilled wells.

The Flatbush Water Works Company, which formerly supplied the Twenty-ninth Ward of Brooklyn, and which was succeeded in 1926 by the New York Water Service Corporation, was originally incorporated February 14, 1881, and had an exclusive franchise for supplying that territory with water. Deterioration of the quality of the supplies furnished by this company, resulting in complaints from consumers, prompted the City to take legal action to acquire their distribution system by condemnation, and water from the municipal system was supplied to this area beginning July 1, 1947.

In the Borough of Queens, the Jamaica Water Supply Company and the New York Water Service Corporation (Woodhaven Plant) furnish water for the Fourth Ward. The Jamaica Water Supply Company, which supplies the easterly portion of the Fourth Ward of Queens, was incorporated April 21, 1887. The Woodhaven Water Supply Company, which supplied the Woodhaven or westerly section of the Fourth Ward of Queens and was succeeded in 1926 by the New York Water Service Corporation, was incorporated February 28, 1888.

The average quantity of water supplied by the private water companies during 1951 is shown below:

Jamaica Water Supply Co.	29.1 m.g.d.
New York Water Service Corp. (Woodhaven Plant)	9.1 "
TOTAL	38.2 m.g.d.

The private companies, except as to rates, are under the general supervision, regulation and control of the Commissioner of Water Supply, Gas and Electricity.

SUPPLY TO COMMUNITIES OUTSIDE OF NEW YORK CITY

Under Section K 41-42.0 of the Administrative Code of the City of New York, it is lawful for any of the municipal corporation or water districts in the Counties of Ulster, Greene, Delaware, Schoharie, Sullivan, Orange, Westchester and Putnam, to take and receive from any of the reservoirs,

aqueducts, conduits, streams or pipes of the City of New York, a supply of water for the uses and purposes of said municipal corporation or water district, upon application made to this Department. Rates are to be based upon the actual cost to the City of New York after deducting fixed and operating charges upon the distribution and delivery system within the city limits; such charges are not to exceed the New York City rates and are subject to review by the Supreme Court. Effective December 1, 1943, the charges were fixed at 78.75 cents per 1000 cubic feet of Catskill water and 52.50 cents per 1000 cubic feet of Croton water.

Chapter 350 of the Laws of 1909 granted similar rights to municipalities in Nassau County to take water from the New York City sources in that County, at prices to be fixed by the Commissioner of Water Supply, Gas and Electricity which, however, were not to exceed the Brooklyn rates.

Many communities have taken advantage of these privileges for securing their entire supply or to augment their supply in period of emergency.

Sing Sing Prison in the village of Ossining is furnished with a supply of Croton water through a connection to the Old Croton Aqueduct at Spring Street under an act of Legislature in 1861 (Chapter 282); the price paid the city is 2½c per 100 cubic feet.

The total amount of water supplied in 1951 to these outside communities and institutions averaged 28.1 m.g.d.

WATER REVENUE

Chapter 30 of the New York City Charter provides that the department shall have jurisdiction, charge and control of making rules and regulations, subject to the approval of the Board of Estimate, fixing meter rates and uniform annual charges and extra and miscellaneous charges for the supply of water.

The Bureau of Water Register determines the charges affecting the water revenue in the city derived from the service, sale or use of water. Other important functions of this bureau are the control of the work incidental to the installation of water meters, prevention of water waste and general supervision of the use of water.

Annual water charges, meter rate charges, charges for services rendered in the repair and installation of water meters and fees for the replacement of meter glasses are determined by this bureau and are transmitted to the Bureau of City Collections, Department of Finance, for billing and collection.

The Bureau of Water Register determines and collects the charges for unmetered water used in the alteration of existing and the erection of new buildings, and if not paid within the time specified by law, such charges are likewise transmitted to the Bureau of City Collections for collection.

It also issues permits and collects the fees for use of water, by boats operating in the harbor, for hosing sidewalks, for sprinkling lawns and gardens, for street paving, for repairs to paving and sidewalk, for subway construction, for sewer building and other public works.

The miscellaneous revenues collected in the Bureau of Water Register are derived from such sources as the insertion of taps and plugs in water mains, shutting off taps, locating taps, meter testing, fire flow test, repairs to lamposts, pole licenses and rentals, electricians' licenses, subpoena fees, and rentals for use of city property.

In 1951 the Bureau of Water Register tended to the mass of detail involved in 667,175 separate accounts of consumers of water; fixing the amount to be paid by 478,277 consumers who pay on a frontage basis; reading the meters of 188,898 consumers whose charges are fixed by meter measurement; transmitting to the City Collector schedules of frontage and meter charges aggregating $42,311,310 and determining charges amounting to $248,300 from the sale of water for miscellaneous uses and $495,058 from sources other than the sale of water.

Frontage rates vary from $6 for a one-story building 16 feet wide to $21 for a one-story building 50 feet wide. To these rates, $3 is added for each 10 feet in excess of 50 feet frontage and $1.50 for each story above the first. The primary frontage rate is predicated upon the building being occupied by one family, containing one bath and one water closet. For each additional bath, $4.50 per annum is added; for each additional water closet $3 per annum and for each additional apartment or family $1.50 per annum.

The above constitutes the major portion of the revenues derived on an annual basis. There are other miscellaneous charges which contribute only a small portion of the frontage revenue.

Under existing laws the Commissioner of the Department has authority to cause water meters to be installed in business premises only. The law, however, gives the owner of a lot or premises the right to apply for a meter. At present substantially all water used for commercial and industrial purposes is metered.

Meter rates are 15 cents per 100 cubic feet.

The so-called frontage and most of the miscellaneous rates, as originally established in the City of New York, remained unchanged from 1851 to the end of 1933. The meter rates remained the same from 1870 to the end of 1933. Beginning January 1, 1934, all rates were increased a flat 50%.

FINANCIAL

The Municipal Water System of the entire City represents an investment of $875,757,310 to June 30, 1951, and the bonds outstanding on that date totaled $652,872,523, these figures including the expenditures on the Delaware-Rondout Project still under construction. The interest, sinking fund and redemption charges for the fiscal year 1950-51 were $33,405,708. The cost of maintenance and operation of the water supply system for that fiscal year was $12,290,279 while the water receipts were $41,100,150.

ADMINISTRATIVE OFFICERS

DOMINICK F. PADUANO.....*Commissioner of Water Supply, Gas and Electricity*

ANTHONY R. DIPAOLA.....*First Deputy Commissioner*

JOSEPH A. HORAK.....*Deputy Commissioner, Borough of Queens*

THOMAS F. BANNON....*Assistant to Commissioner, Borough of Brooklyn*

HERMAN FORSTER....*Assistant to Commissioner, Borough of The Bronx*

Distribution Mains in Use at the End of 1951

	Diameter Inches	Length
Steel	72	100,675
	66	55,637
	60	83,044
	48	228,452
	36	67,175
	30	27,706
	24	1,792
	20	5,247
	16	723
	12	8,670
	10	310
	8	687
	Total Feet	580,118
Cast Iron	60	3,910
	48	543,392
	42	12,629
	36	415,872
	30	264,358
	24	244,531
	20	1,670,021
	16	827,561
	14	36,505
	12	6,790,631
	10	146,712
	8	10,788,040
	6	4,924,151
	6 (hydrant branches)	751,439
	4	255,337
	4 (hydrant branches)	13,356
	Total Feet	27,688,445
Galvanized Wrought Iron	3	24,093
	2½	9,870
	2	269,554
	1½	4,827
	Total Feet	308,344

GRAND TOTAL—FEET 28,576,907

GRAND TOTAL—MILES 5,412.29

Storage Reservoirs in Watersheds

Name	Year first placed in service	*Elevation of spillway feet	Available Storage with flashboards million gallons
CATSKILL WATERSHED			
Ashokan	1915	East Basin 587.1 West Basin 590.0	130,478
Kenisco	1915	357.0	30,573
Schoharie	1926	1,130.0	19,583
Rondout	1951	840.0	48,700
CROTON WATERSHED			
Boyd's Corners	1873	580.0	1,696
Middle Branch	1878	371.6	4,145
East Branch	1891	416.6	5,243
Bog Brook	1892	416.6	4,400
West Branch	1895	503.2	10,427
Amawalk	1897	399.6	7,070
Croton Falls	1911	309.4	14,839
Croton Falls Diverting	1911	309.6	888
Titicus	1893	324.5	7,599
Cross River	1908	329.6	10,898
Muscoot	1905	199.6	5,705
New Croton	1905	201.6	28,110
Lake Mahopac	1870	659.6	575
Lake Kirk	1870	582.6	565
Lake Gleneida	1870	504.6	165
Lake Gilead	1870	496.6	380
Barrett's Pond	1870	778.6	170
White Pond	1896	830.0	200
Total			103,075
BRONX AND BYRAM WATERSHEDS			
Byram	1897	451.5	948
Wampus	1897	455.2	99
Total			1,047
LONG ISLAND WATERSHEDS			
Hempstead	1879	31.8	880
Ponds—Hempstead	1862	...	27
Pines	1862	...	9
Smiths	1873	...	42
East Meadow	1892	...	19
Wantagh	1892	...	44
Massapequa	1891	...	17
Total			1,038

*Elevations refer to mean sea level at Sandy Hook.

Main Aqueducts and Pipe Lines

Description	Limits	Type	Lgth. Miles	Rated Capacity M.G.D.
Catskill Aqueduct (Shandaken Tunnel)	Schoharie Reservoir to Ashokan Reservoir	Grade Tunnel	18	650
Catskill Aqueduct	Ashokan Reservoir to Hillview Reservoir	Cut-and-cover	55	630
		Grade Tunnel	14	
		Pressure Tunnel	17	
		Steel pipe siphon	6	
Catskill Aqueduct (City Tunnel No. 1)	Hillview Res. to Manh., Bx. & Bklyn.	Pressure Tunnel	18	1000
Delaware Aqueduct	Rondout Reservoir to West Branch Reservoir	Pressure Tunnel	45	900
Delaware Aqueduct	West Branch Reservoir to Kenisco Reservoir	Pressure Tunnel	27	1000
Delaware Aqueduct	Kenisco Reservoir to Hillview Reservoir	Pressure Tunnel	13.6	1800
Delaware Aqueduct (City Tunnel No. 2)	Hillview Res. to Bx., Queens & Bklyn.	Pressure Tunnel	20	1000
New Croton Aqueduct	Old Croton Dam to 135th St. Gatehouse	Grade Tunnel	22.5	300*
		Cut-and-cover	1.1	
		Pressure Tunnel	7	
Old Croton Aqueduct	New Croton Dam to Central Park Reservoir	Cut-and-cover	33	90**
		Grade Tunnel	2	
		C. I. and Steel pipe	3	
Bronx Pipe Line	Kenisco Res. to Bx. Distribution	Cast Iron Pipe	15	20
Long Island Brick Conduits	Massapequa Pond to Milburn Pumping Station	Cut-and-cover	7.3	59
	Hempstead Pond to Spring Creek	Cut-and-cover	12.4	76
Long Island 72-Inch Steel Pipe	Suffolk Co. Line to Pitkin Avenue, Brooklyn		23.4	57
Long Island 2-48″ Pipe Lines	Milburn P. S. to Spring Creek		14	50
Long Island Cast Iron Pipes	Milburn P. S. to Old Milburn Res. Efflux. (48″)		1.6	25
	Old Milburn Res. Efflux. to Smith's Pond (36″)		1.4	14
	Spring Creek to Ridgewood P. S. (60″)		0.6	25
	Pitkin Avenue, Bklyn to Ridgewood P. S. (48″)		0.7	25

* South of Jerome Park Reservoir 250 m.g.d.
** Because of needed repairs present capacity limited to 35 m.g.d.

Distribution Reservoirs and Standpipes

Borough	Name	Normal Water level elev. feet	Storage Million Gallons	Source of Supply
Manhattan	Central Park Reservoir	119	1021	Croton
Bronx	*Hillview Reservoir	295	929	Catskill
	Jerome Park Reservoir	134	773	Croton
Brooklyn, Municipal	Ridgewood Reservoir (3 basins)	172	300	Catskill & Long Island
Queens, Municipal	Far Rockaway Standpipe	140	0.3	Catskill
Richmond	Silver Lake Reservoir	228	438	Catskill
	Grimes Hill Standpipe	450	0.2	Catskill

* North of City Line

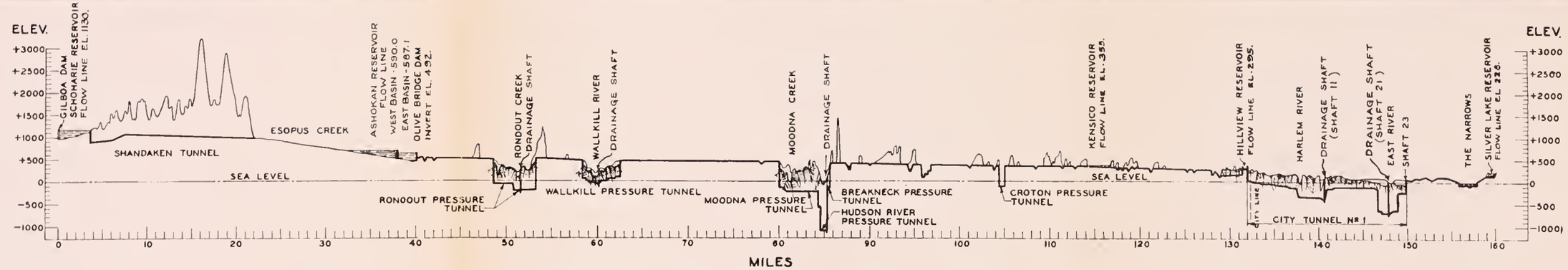
POPULATION AND CONSUMPTION OF WATER IN NEW YORK CITY

Per Capita Consumption Expressed in Gallons Daily; Other Figures in Million Gallons Daily

City							
		Consumption				Supplied by City to Communities Outside of city	Total Cons. Municipal Source
Year	Population	Mun.	Priv. Co's.	Total	Per Capita		
1898	3,272,418	325.0	23.1	348.1	106.4	Not	325.4
1899	3,356,722	349.7	24.0	373.7	111.3		350.1
1900	3,446,042	370.4	22.0	392.4	113.9	tabu-	370.8
1901	3,554,079	376.5	23.6	400.1	112.6		376.9
1902	3,665,825	387.1	25.1	412.2	112.4	lated.	387.5
1903	3,781,423	397.6	25.7	423.3	111.9		398.0
1904	3,901,023	421.2	27.9	449.1	115.1	Prob-	421.6
1905	4,025,742	444.4	29.0	473.4	117.6		444.8
1906	4,166,556	461.8	33.4	495.2	118.9	ably	462.2
1907	4,314,237	477.4	35.6	513.0	118.9		477.8
1908	4,469,248	480.0	38.6	518.6	116.0	did	480.4
1909	4,632,078	480.6	32.1	512.7	110.7		481.0
1910	4,785,190	495.6	32.9	528.5	110.4	not	496.0
1911	4,873,069	461.2	33.2	494.4	101.5		461.6
1912	4,960,948	469.4	35.6	505.0	101.8	exceed	469.8
1913	5,048,827	463.6	35.5	499.1	98.9		464.0
1914	5,136,706	507.5	36.9	544.4	106.0	0.4	507.9
1915	5,224,585	494.6	33.6	528.2	101.1		495.0
1916	5,312,464	526.9	39.3	566.2	106.6	M.G.D.	527.3
1917	5,400,343	545.0	39.6	584.6	108.3	1.0±	546.0
1918	5,488,222	616.0	43.2	659.2	120.1	3.0±	619.0
1919	5,576,101	618.9	41.3	660.2	118.4	0.6±	619.5
1920	5,683,765	689.9	45.0	734.9	129.3	0.4	690.3
1921	5,811,549	684.7	46.6	731.3	125.8	0.7	685.4
1922	5,939,333	703.3	39.2	742.5	125.0	0.6	703.9
1923	6,067,117	723.3	38.3	761.6	125.5	4.1	727.4
1924	6,195,251	738.3	41.9	780.2	125.9	4.0	742.3
1925	6,323,035	794.4	45.2	839.6	132.8	6.7	801.1
1926	6,450,819	814.5	48.8	863.3	133.8	9.0	823.5
1927	6,578,603	816.6	51.5	868.1	132.0	8.0	824.6
1928	6,706,737	825.2	52.6	877.8	130.9	10.7	835.9
1929	6,834,521	883.5	60.2	943.7	138.1	19.0	902.5
1930	6,944,000	920.8	64.5	985.3	141.9	21.5	942.3
1931	6,995,000	883.4	57.2	940.6	134.5	20.6	904.0
1932	7,047,000	877.6	58.1	935.7	132.8	21.6	899.2
1933	7,101,000	880.7	57.8	938.5	132.2	16.8	897.5
1934	7,153,000	902.2	58.5	960.7	134.3	17.0	919.2
1935	7,206,000	891.6	58.5	950.1	131.8	19.5	911.1
1936	7,258,000	913.1	59.4	972.5	134.0	19.5	932.6
1937	7,311,000	916.0	59.3	975.3	133.4	17.4	933.4
1938	7,363,000	920.3	60.0	980.3	133.1	17.9	938.2
1939	7,415,000	938.0	*64.1	1002.1	135.1	22.9	*961.9
1940	7,466,000	862.3	*60.4	922.7	123.6	21.6	*884.5
1941	7,395,000	900.8	*63.4	964.2	130.4	24.8	*926.5
1942	7,292,000	846.6	*60.1	906.7	124.3	21.5	*868.5
1943	7,087,000	879.5	*63.2	942.7	133.0	21.5	*901.6
1944	6,986,000	938.6	*66.3	1004.9	143.8	26.5	*965.8
1945	7,231,000	989.1	*67.1	1056.2	146.1	22.0	*1012.6
1946	7,664,000	1046.3	*70.8	1117.1	145.8	24.1	*1072.8
1947	7,772,000	1100.9	*58.1	1159.0	149.1	30.4	*1133.3
1948	7,815,000	1128.5	*43.8	1172.3	150.0	31.5	*1160.1
1949	7,859,000	1124.2	*42.7	1166.9	148.5	36.2	*1161.1
1950	7,903,000	912.6	*40.7	953.3	120.6	29.1	*942.1
1951	7,947,000	1003.1	*38.8	1041.9	131.1	28.1	*1031.8

*includes water supplied from Municipal sources to Private Water Companies in amounts varying from 0.1 to 2.4 m.g.d.

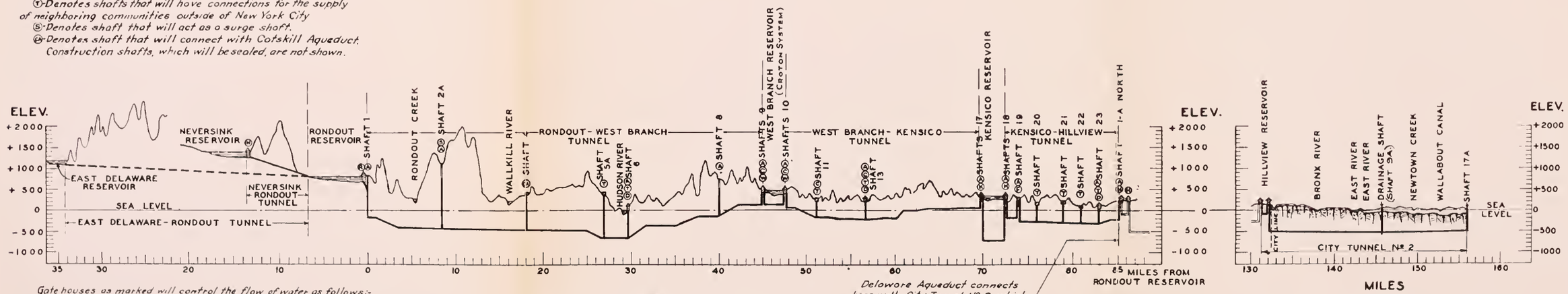
2500—702922 371



PROFILE OF CATSKILL AQUEDUCT AND CITY TUNNEL NO. 1

LEGEND

Ⓐ-Denotes shafts that will afford access to the tunnel.
Ⓒ-Denotes shafts that will connect with reservoirs of Croton System.
Ⓓ-Denotes shafts that will contain pumps for emptying tunnel.
Ⓣ-Denotes shafts that will have connections for the supply of neighboring communities outside of New York City
Ⓢ-Denotes shaft that will act as a surge shaft.
Ⓓ-Denotes shaft that will connect with Catskill Aqueduct.
Construction shafts, which will be sealed, are not shown.



Delowore Aqueduct connects here with City Tunnel Nº 2 which was put into service March 31, 1936

Gate houses as marked will control the flow of water as follows:-
Ⓜ-From Neversink reservoir into the Neversink-Rondout tunnel.
Ⓜ-From Rondout reservoir into the Rondout-West Branch tunnel.
Ⓜ-Into and out of the Croton West Branch reservoir or through the West Branch By-Pass tunnel.
Ⓜ-Into and out of Kensico reservoir or through the Kensico By-Pass tunnel
Ⓜ-To and from the Eastview filters when these are built on the site already owned by the City.
Ⓜ-Into and out of Hillview reservoir or through Hillview By-Pass tunnel.

PROFILE OF DELAWARE AQUEDUCT
(UNDER CONSTRUCTION)

CITY TUNNEL NO. 2

26949-2